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**Master Thesis**

# Industry 4.0 Readiness Evaluation tool for SME(Manufacturing) in India

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# Acknowledgement

# Declaration of Authorship

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# Abstract

As technologies evolve, industries must upgrade too, to remain competent in the market. Industry 4.0, Introduced in 2011 by German government is a strategy for Industrial upgradation. This Industry upgradation is an expensive process, which if not done right can incur heavy losses to the organisation. So, the study of an organisations current capability is necessary. This assessment can inform an organisation where they stand in maturity scale concerning Industry 4.0 upgradation. This will inform the organisation on what aspects to consider while upgrading to be more competent in the market.

This study researches into current maturity models already present in the market, study their drawbacks to know why they are not appropriate for Indian MSMEs, get insights on the drawbacks Industries face while implementing Industry 4.0, what are the dimensions one needs to consider checking the maturity of an Indian Manufacturing MSME and how to implement Industry 4.0 projects for success.

This study considers the literature review to get insights about the technologies that Industry 4.0 depend on, research about current maturity models, constraints industries faced. A scoring model is used to know the drawbacks of the maturity models considered and is used to compare the newly proposed model to the previous ones.  A survey is conducted to obtain primary data about the constraints industries face, and also this survey is used as a part of the "Readiness Evaluation Tool" to check the maturity of the surveyed Industry. An interview is also conducted with open ended questions to obtain information not gathered from secondary research.

It is determined that to check the maturity of an Indian manufacturing MSME, one must consider 4 key segments in the Industry – Organisation, to check the strategies and investments done by the Industry; Manufacturing & Control, to check the level of automation and technologies used in the industry; Products, to check the level of digital features included with the product and product customisation ; and Data Management, to check the level of process data usage and IT Architecture in the Industry.

Finally, it was found out that the constraints obtained from primary and secondary research were in correlation. And the average maturity score of the surveyed organisation is 2.23 out of total 4. This implies that Indian MSMEs are yet to implement Industry 4.0 on a larger scale

**Keywords:** Industry 4.0 maturity, Industry 4.0 implementation, Indian manufacturing MSME, Maturity model, Constraints,

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# List of Abbreviations

PLC Programmable Logic Controllers

IT Information Technology

IoT Internet of Things

AI Artificial Intelligence

VR Virtual Reality

AR Augmented Reality

ML Machine Learning

AM Additive Manufacturing

AR Augmented Reality

PwC PricewaterhouseCoopers

MSME Micro, Small and Medium Enterprises

CPS Cyber-Physical Systems

IIoT Industrial Internet Of Things

SCM Supply Chain Management

PPS Production Planning Systems

ICT Information and Communications Technology

CIM Computer Integrated Manufacturing

CNC Computer numerical control

HR Human Resource

1 € (Euro) = ₹ 85 (Indian Rupee)

# 1. Introduction

The first industrial revolution began in the late 18<sup>th</sup> century, with water and steam power engines taking the front lead. Successive industrial revolutions began in the later 19<sup>th</sup> and 20<sup>th</sup> centuries, respectively. This gave a significant boost in production for the manufacturing industries (Vaidya, et al., 2018).

The term Industry 4.0 came to be in a document by the German government published in November 2011 as a strategy for German industries. This concept deals with the integration of industrial technology with communication technology to create a Cyber-Physical System to realise a smart and digital factory. The resulting system is more efficient and productive. It is predicted by Germany's electrical Industry association that there will be a 30% increase in productivity due to Industry 4.0 (Zhou, et al., 2015).

## 1.1 Focus and relevance of research

Currently in India, MSMEs contribute to 30% of the Indian GDP and 49.5% of Indian exports (Press Information Bureau, Govt. of India, 2021). With 63 million enterprises in the market (Statista, 2021), Industry 4.0 upgradation can give a strategic advantage over the competitors for an Industry.

The share of GDP that MSMEs contribute to has been consistent although having great potential and beneficial government policies. In these situations, being the first ones to implement Industry can facilitate growth in an organisation and put it miles ahead of their competition (Das, et al., 2022). But during the upgradation of these industries, they face many challenges that might be a de-motivating factor to invest in this novel technology

The upgradation of these industries calls for the assessment of current Industry capabilities. Various dimensions to include all the aspects of an industry's operations needs to be identified and considered during this assessment. Further, without structured planning, the implementation of Industry 4.0 can encounter hurdles.

## 1.2 Research Question

- What are the drawbacks of current maturity models/ Industry 4.0 readiness assessment tools?
- What resistances do Indian SMEs face during industry 4.0 upgradation?
- What dimensions need to be considered during industry 4.0 upgradation for a manufacturing SME in India?
- How can an Indian SME implement Industry 4.0 successfully?

## 2. Background

## 2.1 Industrial Revolution – A brief history
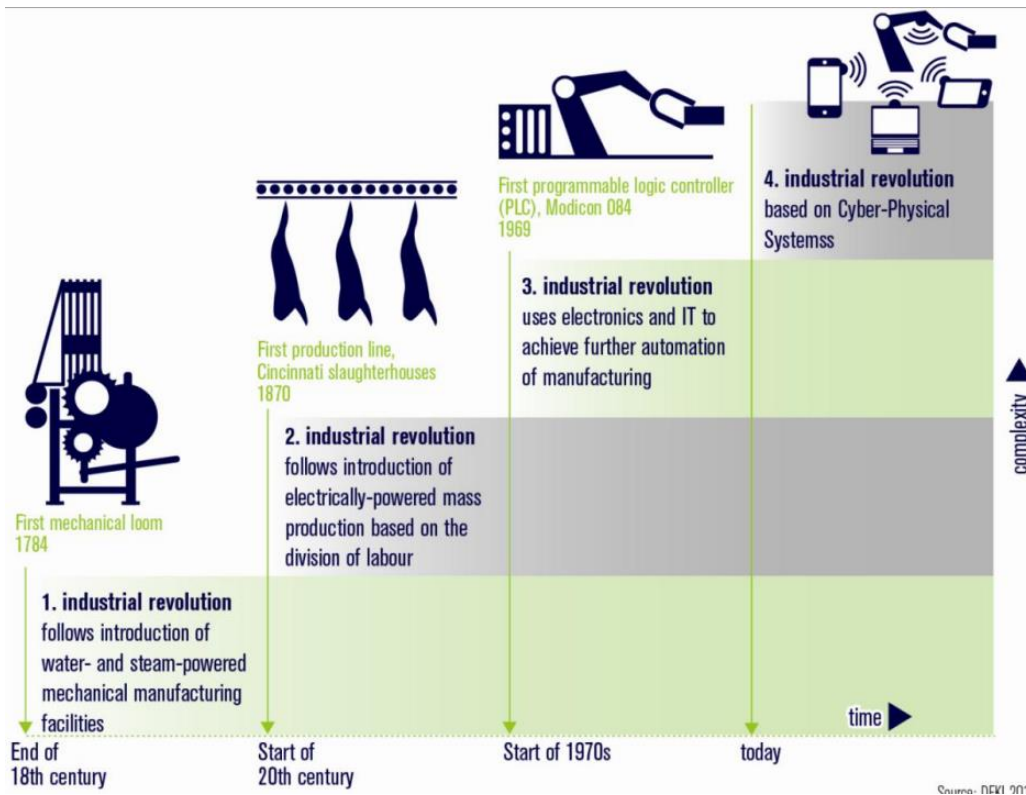


*Figure 1 Industrial Revolution (DFKI, 2021)*

The above figure shows the industrial revolutions through the ages pictorially. The pioneers during each revolution too are depicted.

### 2.1.1 First Industrial Revolution

Thomas Newcomen, an English inventor, developed the prototype for the first modern steam engine in the early 1700s. This paved the way for the First Industrial Revolution. His innovation, known as the "atmospheric steam engine," was initially used to power devices that pumped water out of mine shafts. (history.com editors, 2019)

James Watt, a Scottish engineer in the mid-1700s, modified Thomas Newcomen's design and made it more efficient by adding a separate water condenser. Watt then partnered with Matthew Boulton to design a rotary-motion steam engine, a significant breakthrough that enabled steam power to expand throughout British industries such as flour, paper, and cotton mills, iron works, distilleries, waterworks, and canals. Thus, England became the birthplace of the Industrial Revolution. (ibid)

The Industrial Revolution became a period of growth in Europe and America in the second half of the eighteenth century that saw mostly rural, and agricultural communities

converted into industrialised and urban societies. Thanks to the advent of new machinery and technologies, textiles, iron production, and other sectors, goods that had previously been carefully fashioned by hand began to be mass-produced in factories in large quantities. (ibid)

Ever since the first industrial revolution began, human technology has permitted and supported a succession of disruptive innovations in the field of Industrial production. With the invention of steam-powered and water-powered mechanical machines and their application in industries revolutionised the manufacturing sector. (Devezas, et al., 2017). Steam engines transformed the traditional mills & factories. They replaced the previously were manpower to increase productivity. (history.com editors, 2019) .

One such example is a traditional sawmill which saw huge advancements. Trees that were originally cut and chopped by hands using huge amounts of labour could now be done by machinery. Steam engine fixed to a saw could chop wooden barks at never-before-seen speeds. New businesses sprung up who were selling these mills, as shown in figure 2.

*Figure 2 An advertisement for a sawmill steam engine (history.com editors, 2019)*

### 2.1.2 Second Industrial Revolution

America gained its independence from England in the late 1700s, and it imported most of its manufactured goods from England (Mohajan, 2020). First, factories such as British textile mills built in England slowly then spread to the United States during the first industrial revolution (Niiler, 2019).

Further technological developments in the field of electrically powered machines initiated the second industrial revolution in the late 19th to 20th century. Division of labour and the advent of mass production machines powered by electricity further increased the efficiency of the manufacturing sector. (Devezas, et al., 2017). Vaclav Smil called this

second industrial revolution period as the "The age of Synergy". This period witnessed many technological advancements, their rapid commercialisation and refinement to benefit the consumers. These remarkable technological advancements established the long-term foundations for present-day societies defining materials, economics, consumption, and social patterns of today's standards. (Smil, 2005).

An American inventor named Oliver Evans designed a more powerful steam engine than James Watt; in 1846, another American inventor – Elias Howe invented the "Sewing Machine"; in 1862 "Gatling Gun", the first automatic machine gun was invented by another American - Richard Jordan Gatling; Thomas Alva Edison, an American inventor revolutionized by inventing "Light Bulb", "Phonograph" and "Kinetograph"; and an American engineer Robert Fulton used the steam engine to create a steam boat, which revolutionized the sector of speed travel on water. Further modifications to design efficiency increase of a steam engine changed the transportation industry and made steam-powered railways & ships more economical and mainstream (Mohajan, 2020).
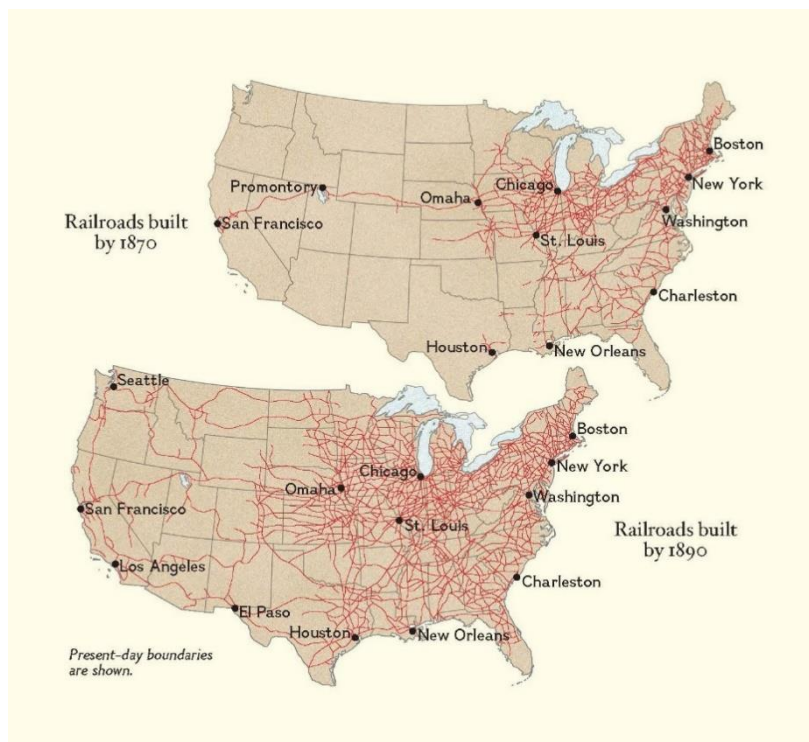


As steam-powered railways became more economical, this saw a huge number of people wanting to travel in this new way of travelling and transportation of goods becoming more economical. Figure 3 shows the map of the railroad system in the USA before and after the second industrial revolution, evidently showing the wide acceptance of people towards the transport system. Thus, the period of Second Industrial revolution is also referred to as "American Industrial Revolution" (Chen, 2021).

*Figure 3 Railroads built in the USA during Second Industrial Revolution (National Geographic Society, n.d.)*

### 2.1.3 Third Industrial Revolution

In the year 1968, Dick Morley built the first Programmable Logic Controller (PLC). Shown In figure 4 is Dick Morley with the first PLC he invented - Modicon 084. This changed the thinking of process design, where now PLCs replaced the traditional hard-wired systems

that were complex and difficult to change. (Modicon, 2017) These PLCs, along with the advent of the internet and improved connectivity, paved the way for the third Industrial revolution in the late 20th century. By using machines with PLCs, IT systems and electronics further automation in manufacturing was achieved with production lines now being automated. (Supply Chain Game Changer, 2018). This substantially reduced the human effort, achieved great accuracies and rapidly increased the speed of manufacturing.

*Figure 4 Dick Moreley (extreme left) with Modicon 084 (Radwell International, 2018)*

### 2.1.4 Fourth Industrial Revolution

Further advancements in the field of digital technology and usage of emerging technologies such as AI, robotics, VR, AR and ML in the field of manufacturing resulted in the fourth industrial revolution (Dang, 2019). With Its main characteristic being the application of the cyber-physical system, which links people, real surroundings and virtual objects via data links such as the Internet of things (IoT), cloud technology to achieve greater automation, the term Industry 4.0 was first coined in the year 2011 at one of the world's largest trade fairs – Hannover Messe as a high-tech strategy of the German industry. (Devezas, et al., 2017).

*Figure 5 Automated Production Line of Tesla*

While Industry 3.0 focused on automation of machines and processes, Industry 4.0 is centred on complete digitisation of all assets and their integration with each other in digital ecosystems (Geissbauer, et al., 2016). In industry 4.0 there is availability and usage of

vast amounts of data obtained through interconnected machinery, into the production process for better efficiency (UpKeep, 2019). Shown in figure 5 is the automated process line of Tesla Inc. 75% of Tesla's production lines are automated with the help of industrial robots and other cyber-physical systems and function without any human intervention. (Aregay, 2020)

## 2.2 Industry 4.0 Concepts

### 2.2.1 Nine Pillars of Industry 4.0
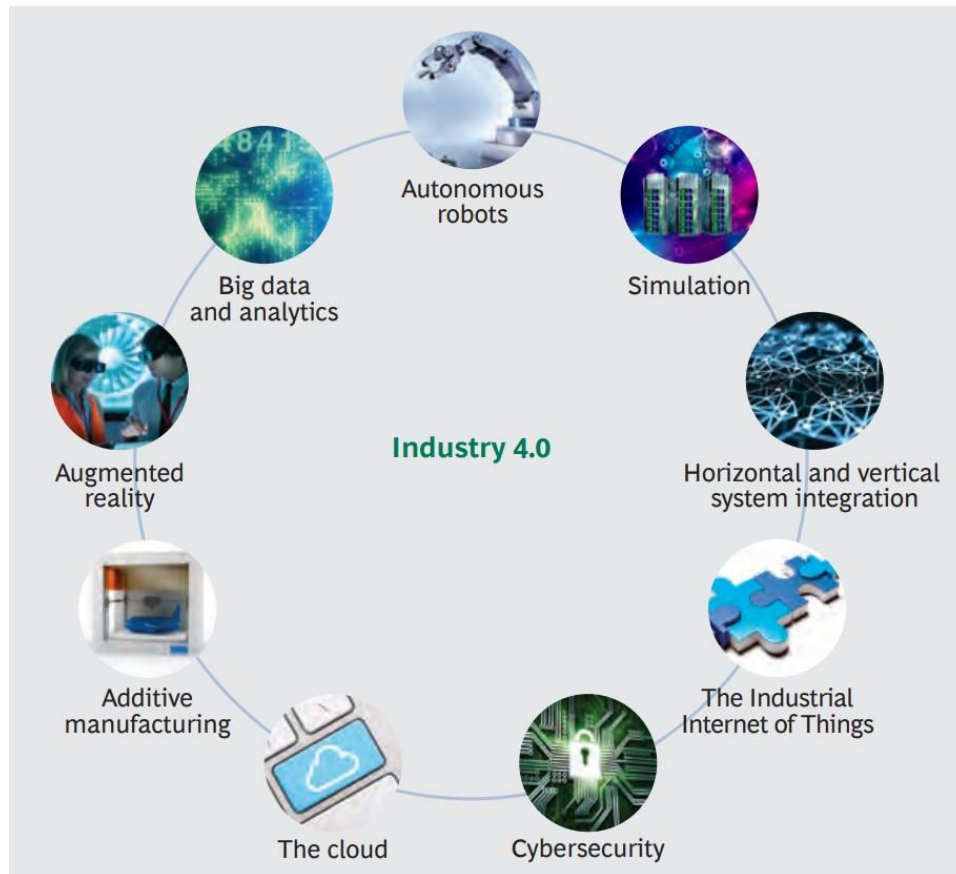


*Figure 6 Nine Pillars of Industry 4.0 (Rüßmann, et al., 2015)*

Boston Consultancy Group has identified nine key elements that describe industry 4.0 in a manufacturing and production industry – shown in Figure 6

**Big Data and Analytics –** Large data sets obtained from manufacturing equipment, enterprise management and customer management systems can be analysed for advancements such as the optimisation of quality, efficiency improvement and equipment life. These data would help in real-time decision making. (Rüßmann, et al., 2015)

**Autonomous Robots –** Robots have already been used in industries before but in Industry 4.0, robots are aimed to be interconnected, adaptable and more autonomous. As

technology advances, these robots are said to be more affordable by the industries while increasing in their range of capabilities. (ibid)

**Simulation –** The engineering phase in a production cycle already uses 3-dimensional models of products, materials and manufacturing processes, but Industry 4.0 aims to use 3-dimensional modelling of plant operations, with virtual representations of equipment, workers and products. This would help workers to test and refine the machine setting beforehand, thus reducing machine setup times by up to 80%.

**Horizontal and Vertical System Integration –** The majority of IT systems in an industry lacks interconnection. Businesses, vendors and users lack data interconnection. Interdepartmental integrations between engineering, manufacturing and maintenance departments are also lacking. Industry 4.0 aims to interconnect the business, departments, activities so that the manufacturing processes become more automated. (ibid)

**Industrial Internet of Things –** Only some of the manufacturer's equipment and products have embedded systems in them. These systems help in the process of interconnection and help communicate and engage with other equipment. Industry 4.0 aims to include these embedded systems in more devices, even including unfinished products. This allows for real-time responses by decentralising decision making.

**Cybersecurity –** Many Industries still depend on isolated manufacturing and management systems. But with Industry 4.0, machines and planning systems are being more connected and autonomous. This increases the need for systems to counter cyber security threats. Thus the need to work with cyber security firms increases.

**The Cloud –** Currently, there is limited usage of cloud technology in Industries, Industry 4.0 requires sharing the data across production sites and corporate boundaries. This will increase the need for the usage of cloud-based technologies, which will be used to drive data-driven services for manufacturing systems.

**Additive Manufacturing (AM) –** With Industry 4.0, additive manufacturing technologies is used for prototyping and also the production of customised products in small quantities. Inventory level and transport distances can be reduced by decentralising these AM Systems.

**Augmented Reality (AR) –** In Industry 4.0, AR systems can be used in a wide variety of applications such as selecting parts in a warehouse, informing a worker with real-time information to enhance their decision making, receiving sets of repair information for a repair procedure. This technology can be deployed by using technologies such as AR glasses which bring information into the field of view of an employee.

## 2.2.2 Four Domains of Industry 4.0



*Figure 7 Four Domains of Industry 4.0 (Davenport & Redman, 2020)*

Davenport and Redman from Harvard Business Review have identified four domains for achieving digital transformation. They are Technology, Organisational Flexibility, Data and Process, as depicted in figure 7. The overall digital performance of an organisation can be hindered if there is any subpar performance in any of these domains.

The most important part of this digital transformation are the people, centred around it. They are the ones who create & alter the strategy and generate and express the vision of the organisation. So mustering the right team with the right skill set and a strong leader to bring about the change, for this transformation is a necessity for its success. This concept provides details of the people needed to achieve success in each of the four domains.

**Technology:**

Internet of things, Artificial Intelligence, data management, machine learning, cloud computing and other Industry 4.0 technologies have the capability to dramatically change an organisation positively. As these technologies are becoming more economical and accessible, organisations will choose to implement them. However, the technology must be understood first, and how this specific technology fits into the needs of an organisation must be analysed, and their implementation must be examined as their integration is a complex task. Old and outdated technologies are difficult to upgrade and will incur additional costs for technology upgrades – technical debt.

Most organisation's IT departments are subpar and focus on only maintaining and operating already present business processes rather than driving any technological changes. These issues can be resolved by employing people with great technical knowledge strategic acumen to make technological decisions that strike a balance

between innovation and dealing with technical debt, good communication and co-operation skill to blend in with the organisation

**Data:**

Most data in organisations today do not meet the fundamental requirements of digital transformation, which requires significant improvement in the field of data quality and analytics. This requires Understanding new types of unstructured data (e.g., a driver-supplied picture of car damage), large datasets from outside the organisation, effective usage of proprietary data available and integrating everything along with disregarding the massive data which is not useful. Although most organisations know and recognise the importance of data management and agree their capabilities are not up to the mark, they fail in assigning responsibilities and IT departments are blamed unnecessarily.

People with motivation capacity is essential to persuade huge numbers of employees on the front lines of businesses to take on new roles as data customers and data providers to gather and use data effectively. They need to be educated and communicated accordingly and assist front-line personnel in improving their work procedures & activities in order to provide accurate data according to the data requirements of the organisation.

**Process:**

The process of this digital transformation is a companywide endeavour, where a new perspective to fulfil customer expectations, manage many cross-functional teams and integration of various work processes are required. However, horizontal cross-functional process management is difficult in an organisation with a conventional hierarchical mentality.

People who have the knack for organising things are well suited here. They need to assign cross-functional teams according to customer needs, to enhance or create a new process. They must also possess judgemental thinking to judge whether gradual process improvement or a major process change is required.

**Organisational Change capacity:**

People responsible for this digital transformation need to be knowledgeable with the components of change management such as Emotional intelligence, leadership, co-operation skill. People who prefer technology, operations and statistics are claimed to be less considerate while judging the "People" part of the change. So, individuals with good people skills are needed to bring about the change.

An in-depth understanding and knowledge of each domain is required to achieve success in the upgradation. However, it is not possible to find a person well versed and suitable to fit each domain. So, talent sourcing specific to the domains is necessary for success. An organisation's upgradation can be compared to the parts of an Aeroplane, where the data is the fuel, the process is the guidance system, organisational change capacity is the

landing gear, and technology is the engine. So, all four domains are required for the successful functioning of a plane or an Industry upgradation.

### 2.2.3 Automation Pyramid

CIM pyramid is modified and built upon by Siepmann to get the automation pyramid. This pyramid consists of six levels that hierarchically describe the level of automation in an Industry. This automation pyramid aims to decrease the difficulties associated with manufacturing in Industries by sorting how the data is obtained and processed hierarchically into these six levels as depicted in figure 8. (Siepmann & Graef, 2016)
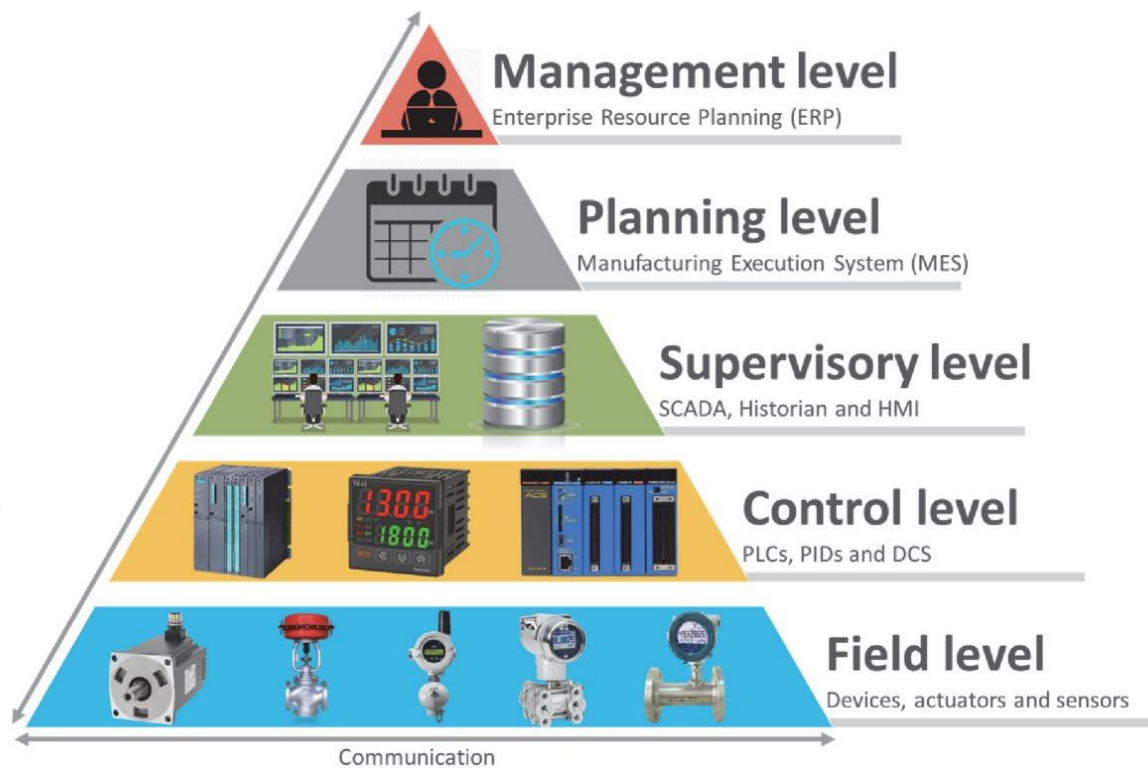


*Figure 8 Automation Pyramid (Rahman, 2021)*

**Level 0: Process level -** This is the starting point of automation in the company. Here RFID chips and other technologies are incorporated onto the workpiece to provide information about its characteristics, movement and production steps.

**Level 1: Field Level -** This is the production level of an organisation where the process of value addition takes place. Here usage of sensors such as temperature sensors or light sensor provides valuable information that can be used to monitor the process.

**Level 2: Control Level -** Here, the signals obtained from the sensors present are fed to a programmable logic controller, which has the ability to trigger a set of actuators that are on the production floor to control the machinery present.

**Level 3: Supervisory/Process Management Level -** This is the level where the human-machine interface takes place. Here by the usage of SCADA systems are used where machines are linked together with computers, which increases the supervision and monitoring capabilities of an organisation.

**Level 4: Planning & Operations Level -** At this level, Manufacturing and execution systems (MES) are responsible for the control and supervision of the whole production process. This computerised process can track and document the movement of raw materials to finished goods.

**Level 5: Organisation management Level -** This is the final stage of the automation pyramid. Here Enterprise Resource Planning systems (ERP) are responsible for the complete functioning of an organisation. This integrated business processes and manufacturing processes.

## 2.3 Industry 4.0 Maturity models and Implementation Strategies

### 2.3.1 Uni Warwick

The University of Warwick developed this tool in association with Crimson & Co, a Global management consultancy and Pinsent Masons, an international law firm. This study makes use of a survey, with 53 responses from 22 different countries, as shown in figure 9. (Agca, et al., 2017)
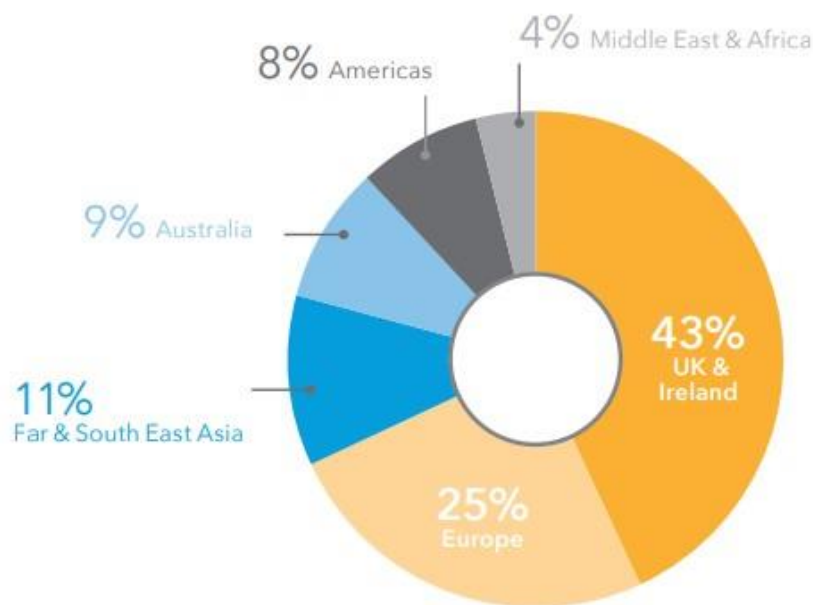


*Figure 9 Uni Warwick survey diversity (Agca, et al., 2017)*

Although the continents in the world are considered in this survey, 68% of its responses are from Europe. No special consideration is given to Indian country with its 11% of responders being from Far and Southeast Asia, among which India is not a part of.

This study formulated six core dimensions and 37 sub-dimensions to assess the industry 4.0 readiness of an Industry. The following are the core dimensions –

**Products and services:**

With the advancements in Industries and technology, the difference between physical products and the digital services they offer are reducing. With the advent of connectivity technologies like IOT, organisations have the opportunity to integrate data-driven services as an add on to their product. This will help organisations add extra value to their products.

Product customisation is one of the things customers value the most. This is one of the main points of Industry 4.0, where a customised product of batch size one can be manufactured at the same cost as mass manufacturing. Organisations can reap the benefits of digitalization by offering customisation in terms of the services offered with a standard physical product. Organisations must also offer data-driven services to the customer to connect with them more and should have a business model such that the majority of the revenue they get should be through the usage of these services.

**Manufacturing and operations:**

The manufacturing plant is the heart of Industry 4.0. Industry 4.0 aims to have a manufacturing facility where completely customised products are manufactured, the workpieces guide themselves autonomously throughout the plant. This facility will have elements of IIOT embedded into their whole plant, where data collection happens in real-time and the data collected is used to optimize the process. Integration of modern technology, human free workplace, data usage and current capability are the four important sectors of Industry 4.0 in a manufacturing plant.

**Strategy and organisation:**

Organisations must educate themselves with the benefit of Industry 4.0 upgradation on their business strategy, products and finances beforehand. Top management executives must understand these benefits to develop strategies based on performance indicators of Industry 4.0. The success of this upgradation not only depends on the monetary value they have spent but also on the acceptance and cooperative way of working of employees. Intense knowledge in the field is also required for the implementation of the formed strategies.

**Supply chain:**

To achieve complete digitalization, organisations must completely upgrade all along their value chains. This digital upgradation will ensure transparency in the organisation. The

success of Industry 4.0 upgradation depends on not only the technological upgradation of the industry but also digitalization across business interactions between vendors and customers. Inter-organisational cooperation is required to collaborate with other organisations to guarantee their support. This ensures digitalization across horizontal and vertical chains. Real-time insights about warehouse and production are the benefits of this upgradation which will encourage agile reaction in the organisation to serve the customers better.

**Business model:**

Industry 4.0 upgradation provides a chance for organisations to improve their business model. Just as offline catalogue retailers had an opportunity to move their catalogue, online manufacturers will have the opportunity to upgrade. Rather than physical ownership of a product, manufacturers are offering them as a service. This allows them to track and monitors their products in real-time to make data-driven decisions such as scheduling maintenances automatically. So, organisations must integrate their marketing, production and business processes to reap the complete benefits of Industry 4.0.

**Legal considerations:**

As Industry 4.0 presents a huge potential for organisations to radically upgrade their production and business processes, it calls for an examination of legal aspects as well. Legal teams informed about the upgradation will be able to foresee any legal complications that may arise and take corrective actions beforehand. Four legal key points to be addressed by the organisation are cybersecurity, patenting, risk identification and usage of contract-based models.

All the dimensions measured are sorted into four scored levels – beginner, intermediate, experienced and expert and is depicted as shown in figure 10.
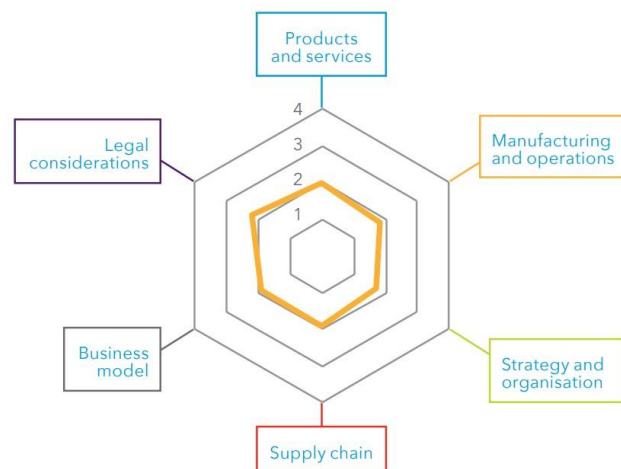


*Figure 10 Uni Warwick Industry 4.0 tool with yellow benchmarking line (Agca, et al., 2017)*

The formulated model can be used to carry out a self-assessment of an Industry and would also serve as a benchmarking tool as it has used data from these 53 industries. The yellow line in figure 8 denotes the benchmarking line obtained from the survey of these 53 industries.

## 2.3.2 IMPLUS

This tool is made by VDMA, a large network organisation that aims to provide a voice for the mechanical engineering industry in Germany and Europe, in conjuncture with Cologne Institute for Economic Research Consult and Institute for Industrial Management, RWTH Aachen, to check the Industry 4.0 readiness of an organisation.

This tool measures the capabilities of an industry with six main dimensions Strategy & organisation, Smart Factory, Smart Operations, Smart Products, Data-driven services, Employees and 18 sub-dimensions covering all the aspects of an industry as shown in figure 11.



*Figure 11 IMPLUS tool (Lichtblau, et al., 2015)*

**Strategy and Organisation:**

This tool suggests that Industry 4.0 must not merely be limited to the upgradation of products and services through new technologies but rather be used pioneer and develop new business models. To track this implementation, the receptivity of an organisation to change and their willingness is assessed by using four key factors - The progress of the Industry 4.0 strategy's implementation, A set of indicators is used to operationalize and assess the plan, Industry 4.0-related investment activity, Management of innovation and the use of technology (Lichtblau, et al., 2015).
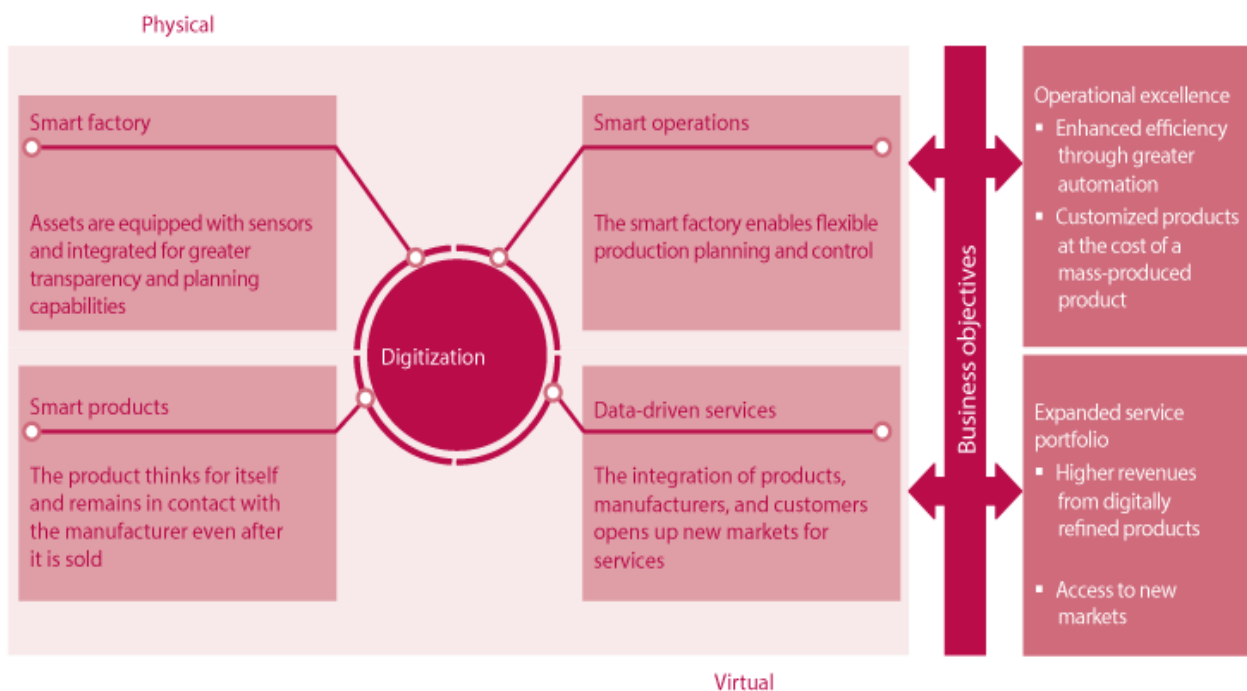


*Figure 12 Relation between different dimensions of IMPLUS tool (Lichtblau, et al., 2015).*

Figure 12 shows the relationship between the physical and virtual world integrated with business processes.

**Smart Factory:**

A smart factory is a place with the successful implementation of Industry 4.0. This will have highly automated production where smart workpieces will monitor & control the production process and will also guide itself through the whole process. In a smart factory, production and logistics systems work independently without any human intervention. Cyber-Physical Systems (CPS) is the main element of a smart factory that Communicates through the Industrial Internet Of Things (IIOT) and other IT systems to link both physical and virtual worlds (Lichtblau, et al., 2015)

In a smart factory, information is conveyed, and available resources are utilized more productively through smart data collection, processing and storage. This involves cross-

organizational coordination in real time between manufacturing systems, data management, and employees. Decision-making models are linked with these large amounts of data obtained to provide an effective solution. The following four key factors are used to evaluate an organisation's progress towards achieving smart factory- Digital modelling, Equipment infrastructure, Data usage, IT systems. (ibid)

**Smart Operations**:

As Industry 4.0 involves complete data integration enterprise-wide, new techniques in Supply Chain Management (SSCM) and Production Planning Systems (PPS) can be achieved by using the huge data that is now made available. Smart operations are achieved through technological advancements in production systems. The following four key factors are used to evaluate an organisation's readiness in the area of smart operations - Information sharing, Cloud usage, IT security, Autonomous processes. (ibid)

**Smart Products:**

One of the main components of a smart factory is smart products. These products not only show their physical value but also will be integrated with RFID tags, sensors and other Information and Communications Technology (ICT) components. This will allow the product to collect data, communicate with other systems and traverse automatically in real-time without any human intervention. By analysing the amount of process date used during manufacturing and the ICT features available for the product, an organisation's "smart products" capabilities can be judged. (ibid)

**Data-driven services:**

Enterprise-wide integration of data and data assessment fuels the after-sales service capabilities and will increase consumer benefits. Smart products with ICT add on can communicate their operational information. This will serve as a base for digital services during product usage. (ibid)

The following three key factors are used to evaluate an organisation's readiness in the area of data-driven services - Data-driven services availability, Data-driven services backed revenue share, Extent of process data used. (ibid)

**Employees:**

Employees are the stakeholders who aid the firms accomplish their digital transformation and are the ones who are most affected by the industry 4.0 developments. Their immediate working environment has changed, necessitating the acquisition of new skills and competencies. As a result, it is increasingly important for organisations to educate their employees about these changes through adequate training education. (ibid)

## 2.3.3 Forrester Digital Maturity Model-

This maturity model was developed by Forrester research – an advisory company that offers consultation and research services. This report builds upon their previous 2014 digital maturity model. (Gill & VanBoskirk, 2016)

This model evaluates core components of a company's total digital transformation, such as leadership support for digital strategy, digital employee resourcing, success measurement, and the efficacy of business functions/IT relationships. This model also looks at competencies related to a company's digital marketing department, such as how effective digital marketing aligns with the organisation\s strategy. The model also considers how digital technologies facilitate sales and service interactions, as well as touchpoint integration and technological sophistication. (ibid)
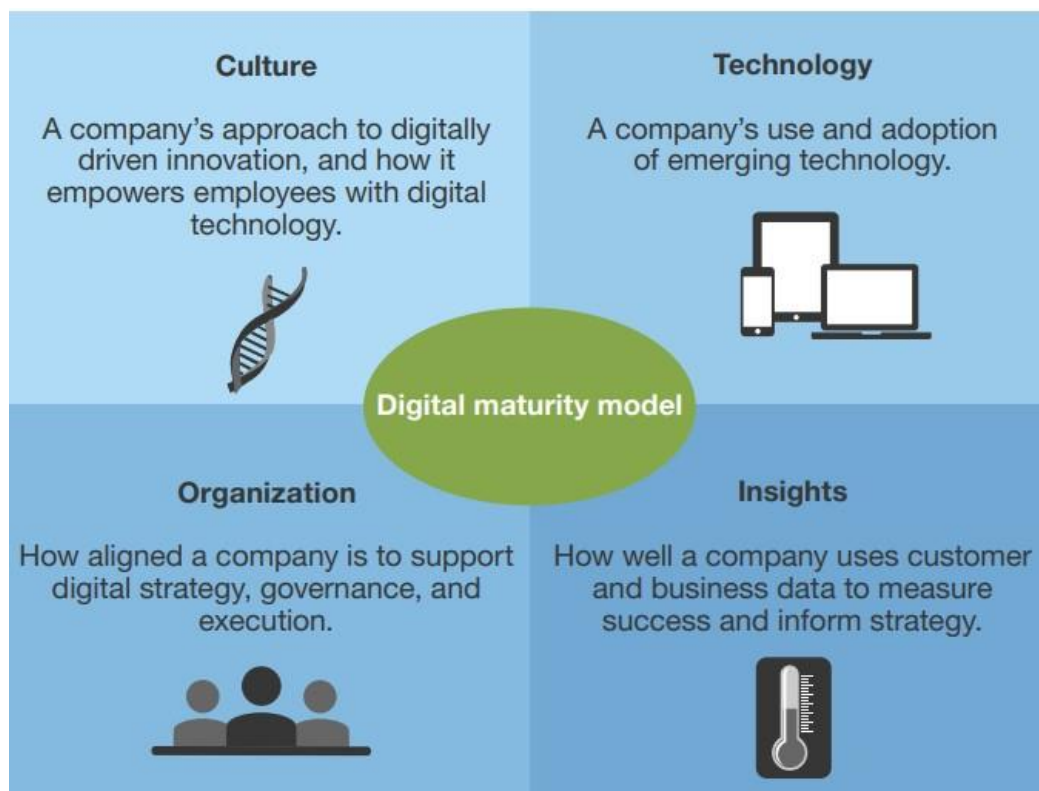


*Figure 13 Forrester Digital Maturity Model (Gill & VanBoskirk, 2016)*

Figure 6 shows the four dimensions Forrester model considers while evaluating maturity.

**Culture** dimension evaluates an organisation's belief, the mentalities of the leaders and management executives, willingness to take measured risks, digital education and communication of the organisation's digital vision. (Gill & VanBoskirk, 2016)

**Organisation** dimension evaluates the structure of the organisation, willingness to commit suitable resources, presence of skilled personnel, presence of digital

technologies, digital competence of business partners and encouragement given to collaborations amongst various functional teams. (ibid)

**Technology** dimension evaluates budget considerations given for shifting priorities, implementation of technology in marketing, an organisation's approach towards technology development, usage and implementation of modern technological architectures such as cloud & APIs, usage of customer experience assets in technology design and usage of digital tools amongst employees(ibid)

**Insight's** dimension evaluates the presence of measurable digital strategy goals, employee knowledge, how the success is measured? Measurement of various channels in the organisation, usage of customer insights in the digital strategy & development and how well experiences learned are incorporated back into the strategies. (ibid)

The four dimensions are quantified in a scoring criterion. The questions are formulated considering all the mentioned points. Each question is scored between 0-3 with 0 = Completely disagree, 1 = Somewhat disagree, 2 = Somewhat agree, 3 = Completely agree. After scoring, the total cumulative score is used to place an organisation in a maturity segment. (ibid)

| | Maturity segment | Characteristic behavior | Strategy | Score range |
|---|---|---|---|---|
| High | **Differentiators** | Leveraging data to drive customer obsession. | Blend the digital and physical worlds. | 72-84 |
| | **Collaborators** | Breaking down traditional silos. | Use digital to create competitive advantage. | 53-71 |
| Level of maturity | **Adopters** | Investing in skills and infrastructure. | Prioritize customer relationships over production. | 34-52 |
| Low | **Skeptics** | Just beginning the digital journey. | Prompt a willing attitude. | 0-33 |

*Figure 14 Segments of Forrester Maturity Model (Gill & VanBoskirk, 2016)*

Figure 12 shows how the industries are distributed according to their cumulative scores. The industries are divided into four groups depending on their maturity level.

**Skeptics:** These are technological novices who do not have sufficient experience in innovating or applying customer-centric strategic planning. Skeptics utilize internet sales platforms sparingly and run few digital marketing campaigns. (ibid)

To help organizations develop a positive attitude towards digitalization of the industry and to make all the stakeholders be aware of the stakes associated with it, skeptics organizations should - Develop a few pathfinding initiatives to get executives interested in it; Integrate digital resources; To attract new digital talent, de-emphasize industry experience (ibid)

**Adopters:** Adopters are more technologically experienced than Skeptics. These organisations are more obliging to invest in basic digital platforms such as CRM (Customer Relationship Management) or eCommerce platforms as a result of the good returns from digital marketing and sales channels. Adopters usually have a higher priority on production than customer relations. (ibid)

To further advance digitally, Adopter organisations should start marketing strategically, should develop all their digital needs such as marketing and development in house rather than outsourcing, have a robust and secure data management system to monitor customer data and get useful insights from it. (ibid)

**Collaborator**: The most important distinguishing characteristic of Collaborators is that they are more likely to work with internal and external teams to allow application of and experimentation with digital technologies. Most Collaborators value their customer experience over their internal factors. They have great cooperation and interactions between IT and marketing. (ibid)

If the Collaborators need to differentiate themselves from their competitors, they should – combine data analytics with innovative strategies, integrate the abilities and technologies according to customer needs, master digital influence in order to increase sales. (ibid)

**Differentiators:** Differentiators report steady growth in revenue and are extensively online-focused retailers who are actively better than average industries at all of the marketing and eBusiness functions. By instantaneously using data generated in the real world, by using digital prowess acquired for innovation and collaboration and by unifying the management of customer satisfaction, marketing and technology under one position, differentiators can further integrate digital technologies in their business. (ibid)
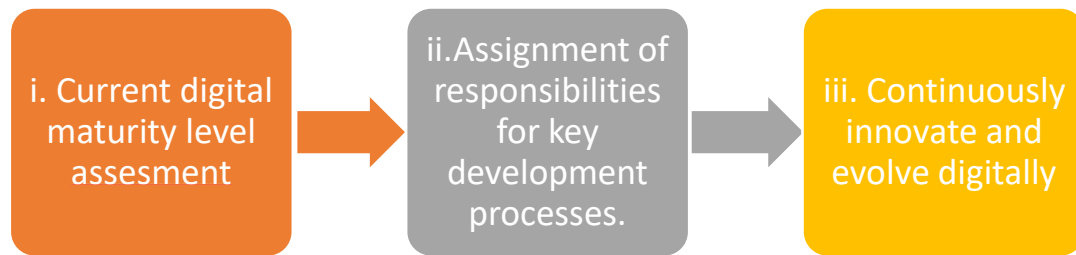
*Figure 15 Forrester Digital Transformation Plan*

Figure 13 depicts the suggested digital transformation plan, a strategic plan for continuous digital evolution and revenue generation. Compared to Skeptics, Differentiators are found to have greater revenue growth. (Gill & VanBoskirk, 2016)

i.   Identifying strong points to promote or gaps to improve can help an organisation to assess their current digital maturity level and to lay the groundwork for their digital strategy while also serving as a comparison point. (ibid)
ii.  Identification of people and positions responsible for key business processes and distributing challenges encountered can help an organisation to mitigate the problems that will come up and distribute the workload uniformly. (ibid)
iii. Digital maturity should be viewed as a continuous effort tuning to the volatility of the market rather than a predetermined state. (ibid)

### 2.3.4 PricewaterhouseCoopers

This research looks into the impact of implementing industry 4.0 and digitisation across the industry's horizontal and vertical value chains. This study was done by considering over 2000 responses in 26 countries, including India and across various types of Industries.
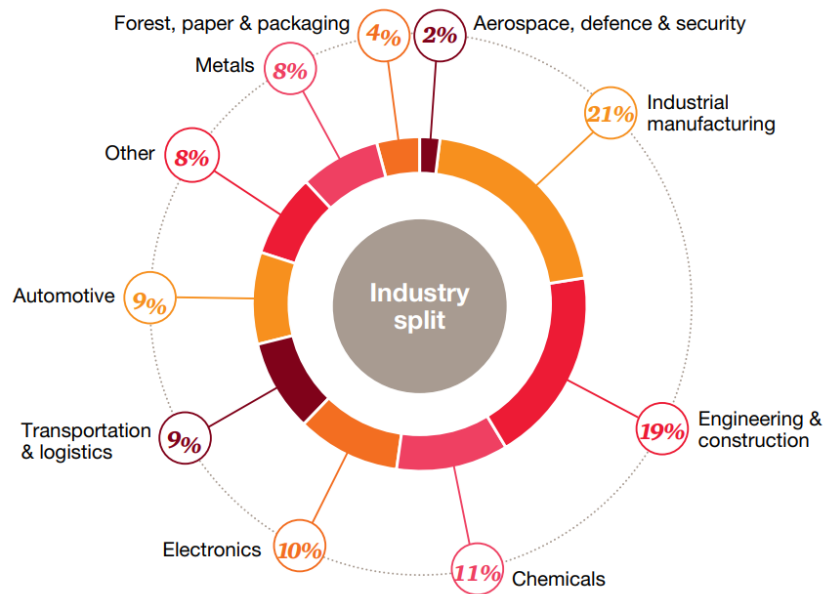
*Figure 16 Industry Split of survey respondents (Geissbauer, et al., 2016)*

This study has a diverse set of responses, amongst which 21% of the respondents are from Industrial manufacturing backgrounds, as shown in figure 16. Although the Indian subcontinent is considered in this study, it is not specific to any one Industry type.

**Industry 4.0 implementation blueprint:** This study provides a blueprint for the implementation of Industry 4.0 shown in Figure 17. It lists six steps hierarchically; an industry should follow for successful implementation of Industry 4.0.



*Figure 17 PwC blueprint for Industry 4.0 Implementation (Geissbauer, et al., 2016)*

It suggests an industry must plan its strategy for the next five years and priorities must be given to the parameters that add value to the business whilst being in line with the organisation's strategy. To have an effective strategy, the organisation's management must be educated and ready. (Geissbauer, et al., 2016)

Initial projects in industry 4.0 implementation, although they might not be a success but would provide valuable experience and knowledge on how to move forward. These pilot projects can be used as examples to demonstrate the value the upgradation brings on. Further funding for bigger projects can be secured using these proofs. For the successful implementation of these small projects, organisations can team up with educational institutions, well-established firms and business new entrants. (ibid)

Based on these experiences, strategies need to be formed by judging the capabilities present, and that needs to be achieved. People will pose a big challenge as skilled workers need to be hired. So, these strategies must also target people along with new technologies and process upgradation. (ibid)

Data organisation and management is one of the main tasks. Data gathered from the machines and manufacturing processes must be channelled correctly to be used in decision making and to enhance the product offering. Small projects should be the starting point in the upgradation, but the organisation must plan for larger projects. (ibid)

To make use of Industry 4.0's complete potential, the whole organisation must undergo a radical change. This requires good leadership where the top management personnel must be dedicated towards this upgradation. Employees must be educated and motivated to not only use the new digital technologies but also to meddle around with them to uncover new ways of using them. (ibid)

Customers must be offered a full suite of products and services. When the organisation does not have the capability to offer some of the services or parts, then partnerships with other organisations must be done to complete the suite. Although it might be scrutinous to let other organisations have our data, a mid-point must be negotiated which would be profitable for everybody. Customer practices must be examined carefully, and strategies must be planned to put your organisation in the centre of the potential network of collaborators, vendors and consumers. (ibid)

This study provides a model to assess the industry 4.0 maturity of an Industry. This considers seven dimensions - Digital business models and customer access; Digitisation of product and service offerings; Digitisation and integration of vertical and horizontal value chains; Data & Analytics as core capability; Agile IT architecture; Compliance, security, legal & tax; Organisation, employees, and digital culture. These dimensions are measured, and industries are ranked as (ibid) –

**Digital Novice:**

In this type of organisation, there is new introduction of digitalisation with some individual applications being digitalised. The product is the main focus of the company rather than the customers. Some of their production processes are automated, and the data collected is mostly manual. Their IT structure is not integrated with different parts of the organisation using different IT systems. And the whole organisation is divided functionally where there is no collaboration. (ibid)

**Vertical Integrator:**

In this type of organisation, digitalisation is advanced towards machine-to-machine communication. Products and services offered are digitalised. Both online and offline channels of distribution are used. The processes and working within the industry is digitalised with easy data movement in the industry. Main business processes are assisted with data collected in decision making. IT structure is uniform across various parts of the organisation. There is collaboration inside the organisations with people from different departments working together. (ibid)

**Horizontal collaborator:**

In this type of organisation, customers are given more priority. Each customer is given a personal experience by digitalising across the value chain. This horizontal digitalisation ensures the data flow with the customer themselves. The data obtained is used to support decision making catering to specific events as well. The IT architecture used in the organisation is uniform with the value chain partners as well to have a single streamlined data input. Legal risks are identified and tackled jointly with the collaborating partners. Collaboration here is not only within the company but also across organisations and different types of people. (ibid)

**Digital champion:**

In this type of industry, collaboration is the central point. Here digitalisation is widespread, and many new and unorthodox business models based around digital technologies are developed. The entire journey of the customer is tracked and tailored for better satisfaction. There is complete digitalisation across both the vertical and horizontal value chain, which results in organisations having the ability to instantaneously access real-time data. IT architecture is streamlined and standardised with the ability for partner organisations also to integrate into the same line. The data collected is processed and managed effectively to not only support decision making but also allows real-time optimisation of processes and analyses of the impacts these decisions have. The entire value chain is skimmed through and polished to comply with the legal needs. (ibid)

2.3.5 A Rolls Royce strategy for Industry 4.0 upgradation
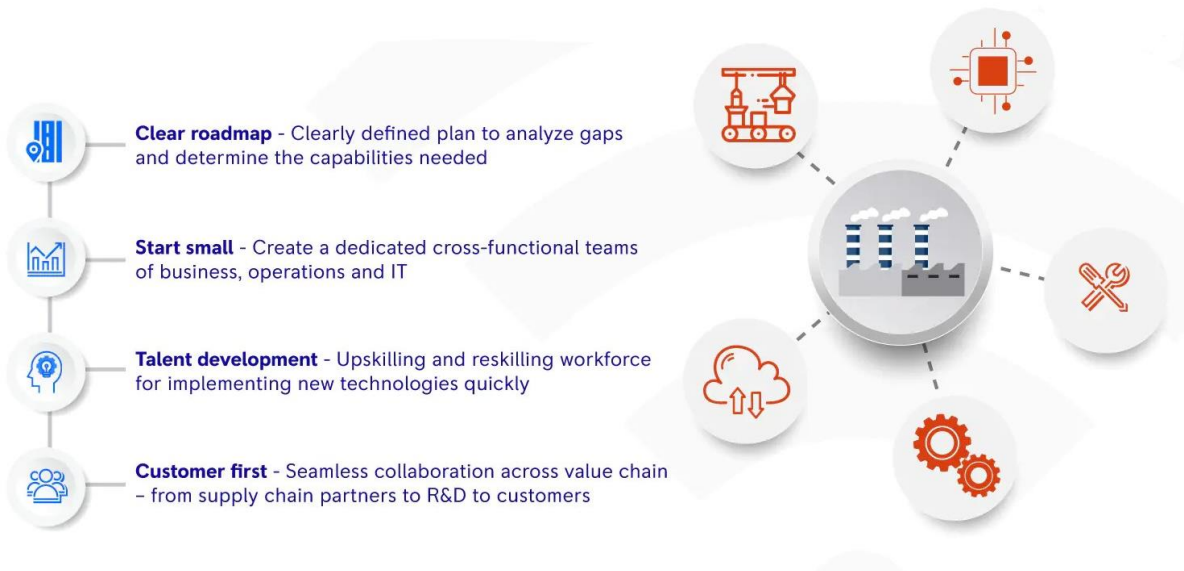


*Figure 18 Rolls Royce Industry 4.0 strategy (Jayaraman, 2018)*

Rolls Royce has suggested four ways industries can implement Industry 4.0, as shown in figure 15 –

**Clear roadmap:** Industries must plan ahead to find the gaps In the implementation of Industry 4.0 and also analyse the current capabilities in place to support this upgrade.

**Start small:** Pilot projects need to be implemented in an industry on a small scale. Assign specific cross-functional silos before scaling up.

**Talent development:** Indian workforce is largely based on low-cost labour, which is unskilled. So, importance must be given to the education of the employees to train and improve their skills. This would ensure a quick implementation of new technologies.

**Customer-first:** Customer satisfaction must be the aim for all manufacturers. Co-operation and join effort of R&D, vendors and customers would ensure faster implementation of Industry 4.0. Collaboration with academic institutions, business organisations and start-ups is also advantageous in this upgrade.

## 2.4 MSME in India

In the Indian classification system, there is a special type of industry smaller than "small enterprises" called "micro-enterprises", and SME classification includes these industries too and is called the MSME sector in India. (Ministry of MSME, 2021). Table 1 shows what constitutes an MSME in India.

| Industry Type | Plant & Machinery Investment | Annual Turnover |
|:---:|:---:|:---:|
| Micro | >₹10,000,000 | >₹50,000,000 |
| Small | >₹100,000,000 | >₹500,000,000 |
| Medium | >₹500,000,000 | >₹2,500,000,000 |

*Table 1 Classification of MSME in India (SHARMA, 2020)*

The government of India classifies Industries based on the capital Invested and revenue earned, as shown in table 1. Micro enterprises are those with one crore rupees in investment and five crore rupees as revenue, small scale enterprises have ten crore rupees in investment, and fifty crore rupees as revenue and medium scale enterprises have fifty crore rupees in investment and two hundred and fifty crore rupees in revenue (Ministry of MSME, 2021) – (1 crore = 10 Million) (Press Information Bureau, Govt. of India, 2021).

Although Indian industrial enterprises constitute over 80% of MSMEs, most of these MSMEs are located in low salaried states rural areas (FMO Entrepreneurial Development Bank, n.d.). Indian business market is a delayed market as there is a lack of financing options available for manufacturers to tap into. There is a big gap between what financing is needed by the industries and what is available to them (German Missions in India, n.d.). This could explain why there is a huge gap in the number of Micro enterprises compared to small and medium enterprises as Micro enterprises are easier to setup with lesser investment.
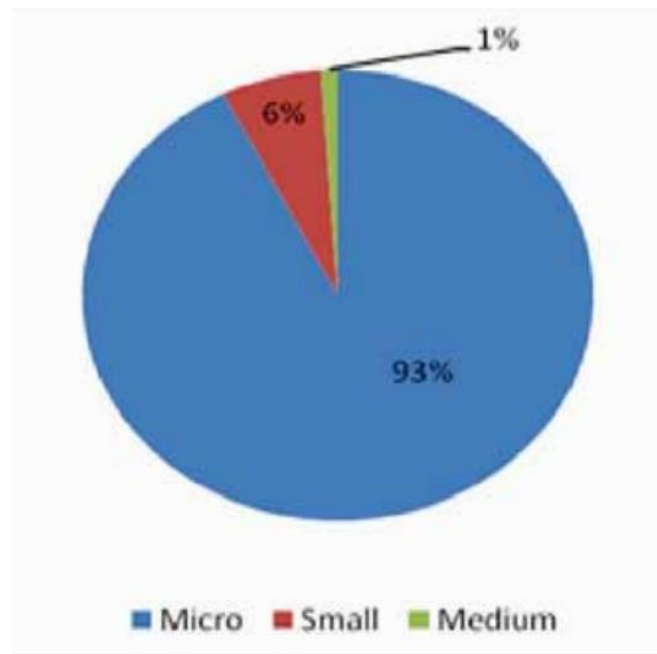
*Figure 19 Distribution of MSME by class (Ministry of MSME, 2021)*

Figure 19 shows how the enterprises are distributed according to the classification of MSMEs. This data is in accordance with "Udhyam" registrations which provides government certificate of registration for enterprises. 93% of enterprises fall under the Micro category, with only 6% and 1% of enterprises coming under the Small and Medium category, respectively (Ministry of MSME, 2021).

MSMEs are one of the important contributors to the Indian economy. These MSMEs made up 30% of Indian GDP and 49.8% of All India exports for the year 2019-2020. (Press Information Bureau, Govt. of India, 2021). With the increase in demand, MSMEs are diversifying with new organisations coming up in various fields.
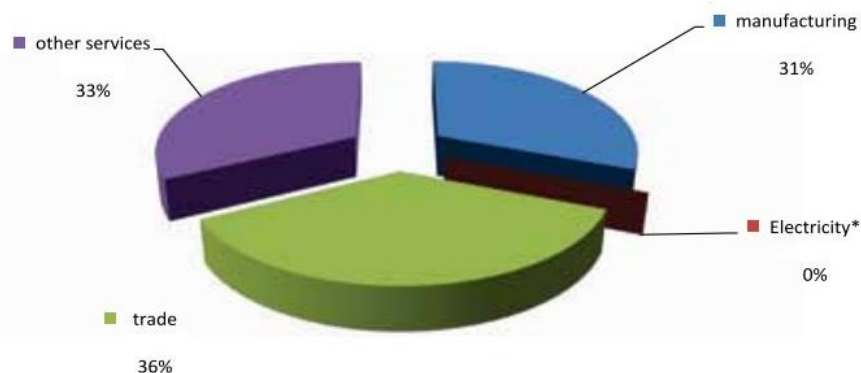


*Figure 20 Classification of Indian MSME based on sector (Ministry of MSME, 2021)*

There are 63.88 million MSME's in India, out of which 19.665 million are manufacturing MSMEs. This constitutes 31% of the total MSME, as shown in figure 20 (Ministry of MSME, 2021). India's manufacturing industry is expected to exceed $1 trillion in value by 2025, according to the Indian government. So, to avail the full benefits of the growing market, industries must strategically plan to invest in Industry 4.0. To advance to the next generation, industries must close technological gaps such as the absence of ICT incorporation and capability gaps such as using obsolete technologies. (Jayaraman, 2018)

## 2.5 Benefits of Industry 4.0
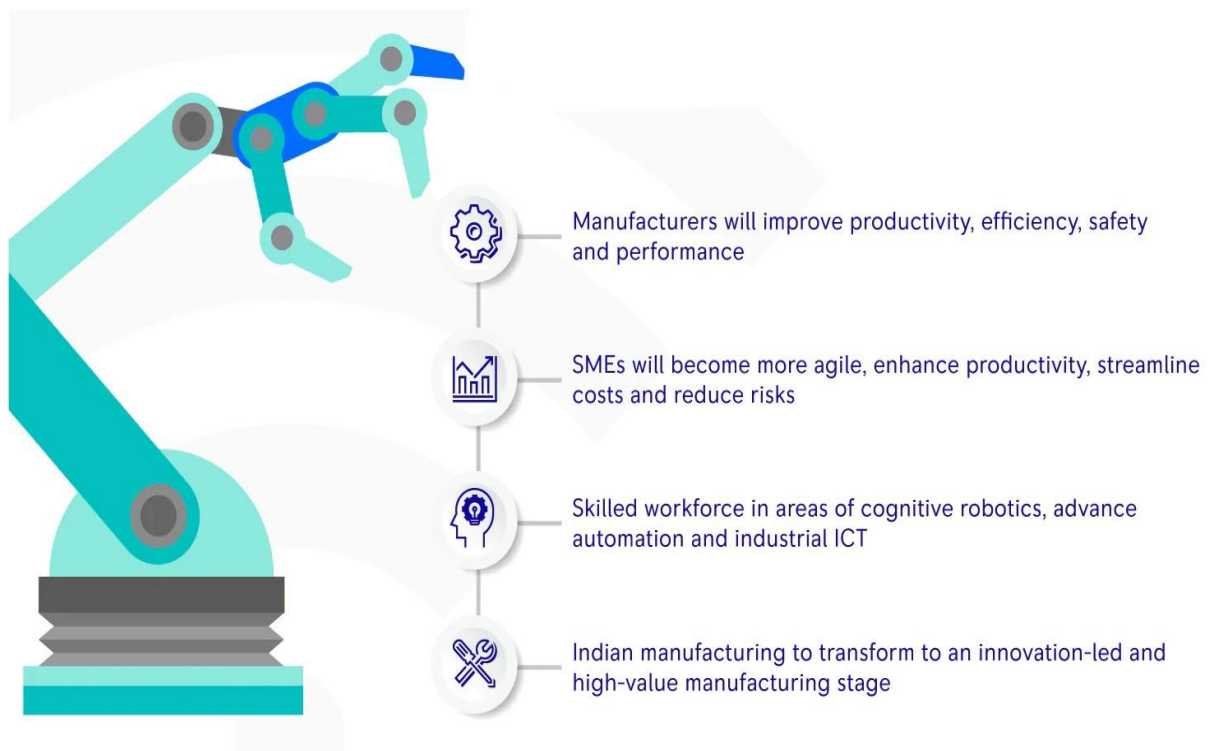


*Figure 21 How India will benefit from Industry 4.0 (Jayaraman, 2018)*

Industry 4.0 upgradation is a long-term strategy that will help an organisation build its brand on a global level. Depicted in Figure 21 is the list of benefits Indian manufacturers will avail from this upgradation. (Jayaraman, 2018) They are -

**Technology-** By leveraging the right process technologies, organisations can monitor the whole manufacturing process from beginning to end across the production process and machinery. This will help them get instantaneous information about the health of manufacturing systems & inventory in the warehouse, which increases their production quality and process efficiency. (ibid)

**Data Analytics-** State-of-the-art data analytics have already been implemented by many online businesses in India. Taking inspiration, similarly, manufacturers can leverage the

power of data analytics to avoid machine downtimes, enhance planning capability, monitor supply chain and boost manufacturing quality and capability. (ibid)

SMEs are the mainstay of the Indian manufacturing sector. For them to grow on a global scale, they need to utilise the benefits of Industry 4.0 to increase efficiency, reduce costs & risks. (ibid)

Industry 4.0 technologies such as robotics, automation, and IIOT requires a new set of skills in the organisation. Machine automation increases the need for safety training. This upgradation will provide an opportunity for the industries to increase the skills of the workforce. Although some jobs might be lost, Industry 4.0 upgradation will generate new jobs related to the skills mentioned above. (ibid)

Innovation based and high-value manufacturing industries such as Aerospace are benefitted the most. Data-driven services will strengthen after-sales service and boost income. (ibid)

## 2.6 Constraints in Industry 4.0 Implementation

The following are the challenges an organisation might face during the implementation of Industry 4.0. The points mentioned below are studied by Pundir with a focus on India.

**Infrastructure Deficit**: Infrastructure and skilled labour according to global trends are necessary for Industry 4.0 upgradation. These industries are further found scattered in rural areas where facilities like electricity, water and roads are a problem. (Pundir, 2018).

**Outdated Technology:** Indian manufacturing MSMEs are lagging behind in the context of industry 4.0 innovation and still use the age-old technologies from Industry 2.0 (Kumar, et al., 2020). This puts them at a disadvantage when compared to cheaper imports from other countries. (ibid)

**Finance:** Banks and other financial institutions help solve a financial problem during industry 4.0 upgradation. However, a high-risk view about this sector amongst banks makes the availability of adequate and quick financing options at fair costs difficult. (ibid). This is more evident in smaller enterprises where there is less cash flow in the organisation.

**Limited Access to Global Markets:** Due to globalisation, foreign companies have found great success in India. However, this is not the same in the case of Indian companies finding success outside India, which is a huge threat to this sector. Some of this sector's limitations while targeting global markets are the usage of outdated technologies, the volume of operations, improper marketing & promotions, difficulties in obtaining institutional funding and fierce competition. (Pundir, 2018)

**Branding and Marketing:** Due to little market exposure, low marketing outputs, and high expenses associated with product marketing, MSMEs' branding and marketing activities

are highly limited. The provenance paradox further makes marketing products from emerging markets like India difficult. (Pundir, 2018). This paradox explains that customers generally connect certain regions with products - such as Italian sports cars or Swiss watches. They generally perceive products emerging from these developed regions to be better and competing items from other regions, especially those from developing markets, to be inferior even though the quality of the product is identical. This causes the inability to fetch a reasonable price. (Deshpande, 2010). Therefore, marketing campaigns and branding strategies should be structured in such a way that there is less opposition for approval of the product amongst the customers. A Strategic technological partnership or a contract manufacturing agreement, or a stake sale or mergers & acquisitions of foreign firms can help MSMEs improve their brand image on a global scale. (Pundir, 2018)

## 2.7 Industry 4.0 and Indian Government

The Indian government has campaigned and solicited numerous foreign direct investments and also implemented a number of beneficial laws in order to promote the widespread adoption of Industry 4.0 in the Indian MSME sector. Internet of Things strategy was developed by the Indian Ministry of Electronics and Information Technology to promote not only the usage of IoT technology across all the potential sectors but also implement IoT training programs to improve the specialised skill set amongst the industry personnel. "Digital India initiative" launched by the Prime Minister of India saw the emergence of the Centre of Excellence for IoT, which aims at indigenously producing IoT components in India to reduce the reliance on imports and to boost the IoT eco-system in India (Das, et al., 2022).

Indian MSMEs need education in the field of Industry 4.0, so in order to increase the knowledge of these manufacturing Industries in the technologies of Industry 4.0, exhibitions and experience centres were put up under the Ministry of Heavy Industry and Public Enterprises' "Udyog Bharat 4.0" and "Smart Advanced Manufacturing and Rapid Transformation Hub" initiatives. (ibid)

Indian governments flagship training programme "Skill India" has widened its courses to include Internet of Things, Artificial Intelligence, and other novel technologies to meet the increasing demand of Industry 4.0. This program aims to increase the skill sets of 40% of India's total manpower in the next five years to be competent for the upgradation. Private Information technology businesses have also joined forces with the government to train well over one million personnel in the "Sills" portal by World Economic Forum. (ibid)

## 2.8 SME 4.0: India compared to the world

Industry 4.0 implementation in an Industry depends on four key factors – Technology factors include the knowledge of Industry 4.0 technology, technological similitude in an industry and flexibility of manufacturing. While the business size, strategies formed are considered in the Business factor. And Industry related factors include regulatory policies,

necessity for upgradation, competitive pressure, and the mindset of the people in the industry to facilitate this upgradation process. (Das, et al., 2022).

Industry 4.0 is considered as a strategic plan by MSMEs in India to meet the productivity and quality standards of the global competitors so as to compete with them in international markets. To design products with great accuracy and precision, technologies such as additive manufacturing is employed. To have better factory operations and efficiency technologies that facilitate machine to machine communications such as robots are used. And Indian MSMEs are using Enterprise resource planning software that integrates with the cloud to monitor the data in real-time. (ibid)

But challenges such as failure to implement horizontal and vertical digitalisation are encountered by these MSMEs due to the necessity that the suppliers also need to be digitalised simultaneously. To add to this, there is also less accessibility of the information about the data format used by them. Also, the real-time information obtained is argued by many to be not necessary for the functioning of the organisation and also the end customers of these industries do not value these insights yet. These factors demotivate the industry to digitalise their value chains. (ibid)

Industries in developed countries such might have a perception that their technologies pertaining to industry 4.0 is better as it is developed by themselves. So, SMEs in these countries such as Denmark and Germany concentrate more on Information technology and communications Industry 4.0 technologies. Whereas Indian MSMEs to improve manufacturing efficiency & quality are funding technologies such as autonomous robots and 3D printing. Lack of digital standards and cybersecurity is a challenge in India as well as Germany. 40% of German SMEs lack a digital strategy in their organisation. But this is not a huge setback in India as the technology is still immature and the competitors also lack access. (ibid)

Although Industry 4.0 has the opportunity to increase revenue, efficiency of an industry, employment and cam be considered as a valuable investment in an Industry; major resistances such as lack of skilled labour, lack of management support, non-existent standardisation hinder the implementation of Industry 4.0, reveals a study of SMEs in European North Sea region. (ibid)

Technologies such as Augmented Reality, Machine Learning and 3D printing are more favourable by SMEs in UK. This is due to them being less complicated and highly advantageous Industry 4.0 technologies. Similarly, it is seen that Indian MSMEs also favour technologies such as 3D printing. (ibid)

# 3. Methodology
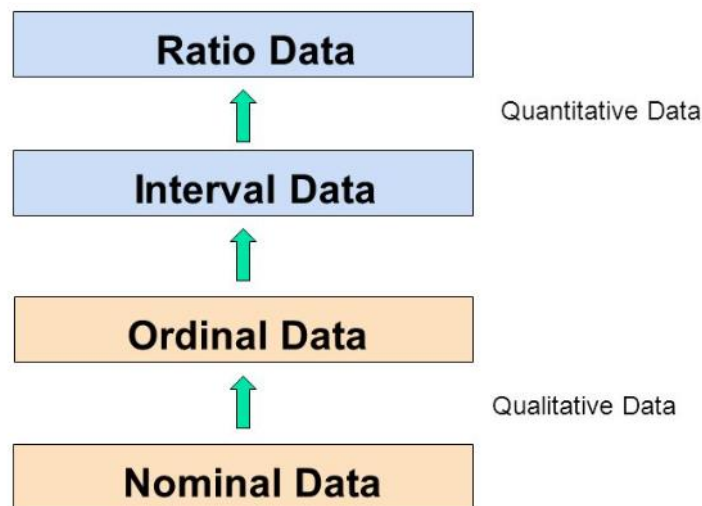


*Figure 22 Types of Data (Graph Pad, 2019)*

Data obtained during a study or research is classified into two main types and four subtypes as shown in figure 22. They are –

**Qualitative Data**: This data is explanatory and theoretical in form. Words and sentences make up the gathered information. Sentiments, thoughts, or opinions of the subject are frequently captured in such data. Unstructured data is generally gathered, and "How and Why" of a subject is answered by employing open-ended questions. (Sajjad Kabir, 2016)

Nominal Data: This is a category of qualitative data where no natural order is there for the data. (Harvard Law School, n.d.) Nominal data such as Organisation name, geographical location and email id are used for this study.

Ordinal data: This is yet another category of qualitative data where the concurrence of the person responding is gauged. (Harvard Law School, n.d.). This type of data is used in this study while forming the questionnaire to know the current strategies of the organisation with respect to the upgradation of the industry.

**Quantitative data:** These data are numerically expressed and are expressed as a subject's measurement. They use a methodised procedure to answer the "What" of a subject. (Sajjad Kabir, 2016)

Interval data: This is a category of quantitative data where might not be any zero point, but logical explanation and reasoning is given and data is inferred as intervals.

Ratio data: This is also another form of quantitative data where a logical zero point is expressed and numerically measured from there.

## 3.1 Secondary Data collection



*Figure 23 Secondary data types*

Secondary data is the data obtained from a source that has previously been published. The literature review is the basis for obtaining secondary data. This type of data is needed to gauge the past efforts on the particular subject in order to effectively conduct research. (Sajjad Kabir, 2016).

To maintain the reliability of the information obtained, types of secondary data used in this study are used in the order as depicted in figure 23.

**Journals:** Journals articles are scholarly publications authored by researchers and other experts. Online journal aggregators such as Research gate and IEEE make obtaining a reliable source of secondary data from journals easier.

**Books:** Published print media includes books released on a particular topic. This would give a reader the current situation and also get the perspective of experts on the subject gained from their experiences. (Nitisha, n.d.)

**Organisational Report:** Sales data, balance sheet, annual report, and other organisational reports makes first-hand data from organisations available to all. This can help to track the growth of the particular industry or sector and also helps to identify gaps by evaluating if an organisation is operating in accordance with its goals. (ibid)

**Website:** Data obtained from articles on the website provide real-time information about the subject in the study. Information from credible web sources such as Harvard Business Review provides valuable insights that add on to the study.
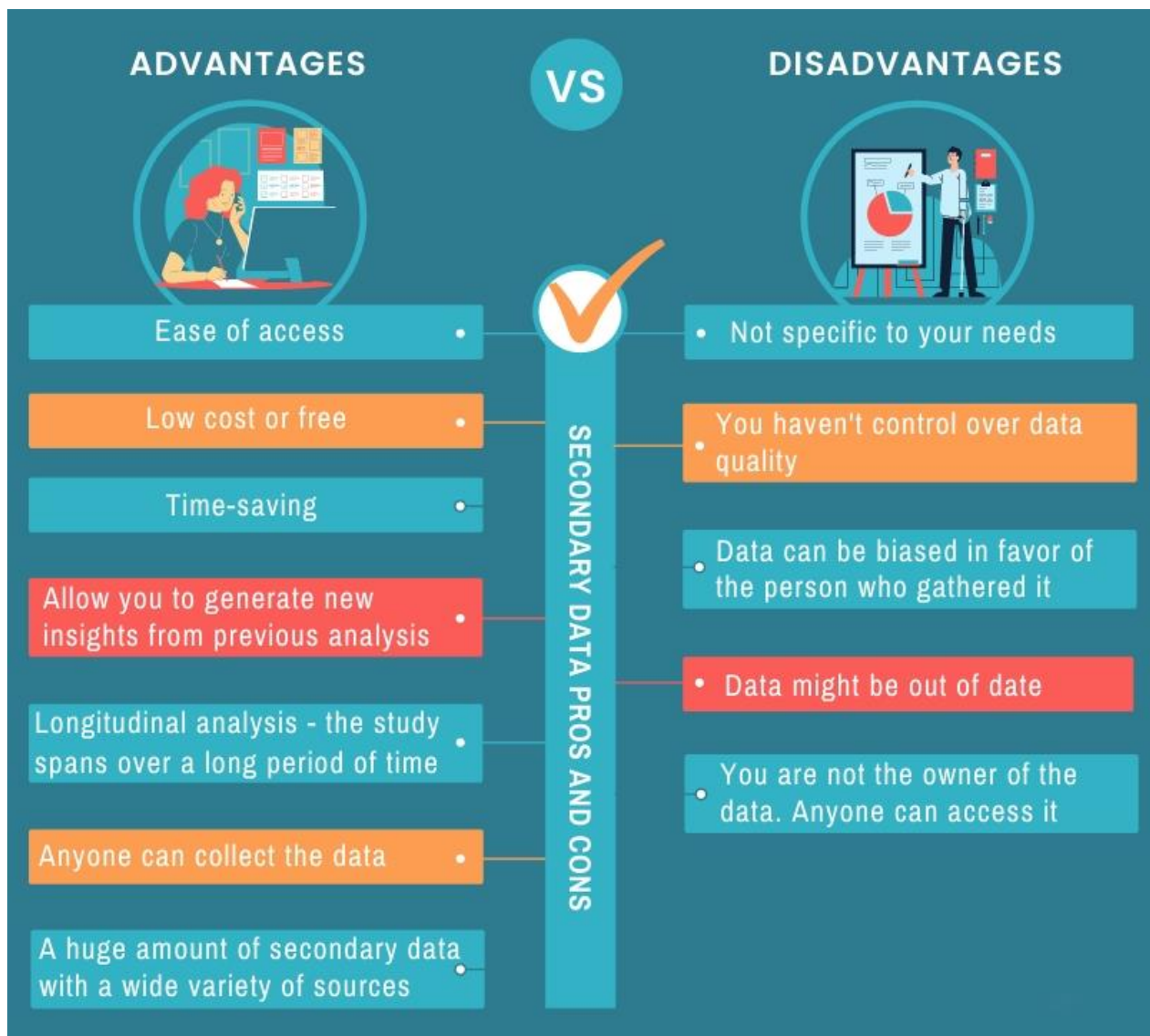


*Figure 24 Advantages and disadvantages of Secondary data (Valcheva, n.d.)*

Secondary data has the advantage of being less expensive and also negates the difficulties faced during data collection and also has the disadvantage of the data sources authenticity and credibility. The advantages and disadvantages are depicted in figure 24.

## 3.2 Primary Data Collection

Primary data is the first-hand data collected by the researcher themselves. This data has more reliability as it has not been published yet. The advantages are the credibility as the collected data is specific to the study. The disadvantage of this data is the hassles of data management and filtering out credible responses. (Sajjad Kabir, 2016)
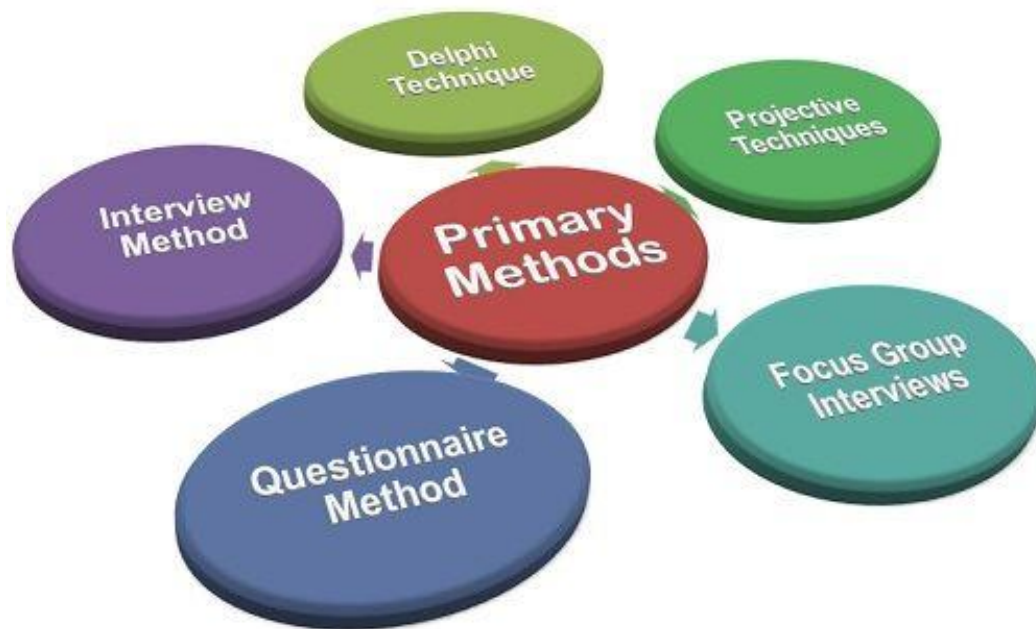


*Figure 25 Primary Data Collection Methods (Business Jargons, n.d.)*

There are many types of primary data collection, as shown in figure 25. Amongst them, survey/questionnaire methods and interview methods are used in this study.

### 3.2.1 Survey

This method of data collection is the most widely used business research. (Adams, et al., 2007). The target audience of this survey is management personnel working in manufacturing MSMEs in India. This method of collecting data is used in this study with the intent that as most people this survey is intended for might not be available for an interview and as surveys are less intrusive and can be answered at their leisure, the response rate might be positive.

The objective of this survey is to reach out to manufacturing MSMEs with an intent to judge the organisation's capabilities with respect to the upgradation of Industry 4.0. This survey is semi-structured with both open-ended and closed-ended questions. Open-ended questions allow the responders to provide their own answer in addition to the options provided in the survey. This will help in providing a new perspective for the

research, as answers which are not expected might appear. Closed-ended questions with pre-determined answers are provided. These predetermined questions are provided with scoring to give industries a score that reflects their current maturity level.

This type of data collection being the most important part of a primary data collection (Aryal, 2019), should be able to reach the correct set of responders to get useful data. Manufacturing SMEs in India are scouted through websites such as linked in and personal contacts are also used to reach the target responders. The responders are also requested to share amongst their network to reach the target responders.

### 3.2.2 Interview

In addition to the survey method of primary data collection, an expert interview is also conducted. Although this method is time-consuming this allows for the collection of large amounts of information (Adams, et al., 2007). In the survey mentioned above, through the data privacy segment, the identity of the person answered can be found out. Amongst them, one industry is selected, and an interview is conducted with the industry specialist from that Industry.

Similar to the survey conducted, a semi-structured way of interviewing is conducted. As Griffee suggests, prior planning must be done to decide who should be interviewed, where they should be interviewed, on what topics the questions should be asked, what type of data is collected and when to stop an interview (Griffee, 2005). An Industry expert from India is selected through the information from survey as explained above and the Interview is carried out online on Skype platform as the concerned Industry is in India.

The main aim of this interview is to gain knowledge on the topic of Industry upgradation to get more insights on the strategies of the organisation, difficulties faced, and digital technologies implemented. Open-ended questions asked in the interview have the ability give the study a new perspective about a topic, which might have not been considered in the surevys.

## 3.3 Structure

The structure of the thesis primarily includes a secondary data collection. Analysis is carried out based on the data obtained from the secondary data sources for the formation of the maturity model and the strategy - Industry 4.0 implementation outline. Primary data collection methods used – Surveys and Interviews are used to gauge the maturity as well as to validate the data collected from the secondary data collection.
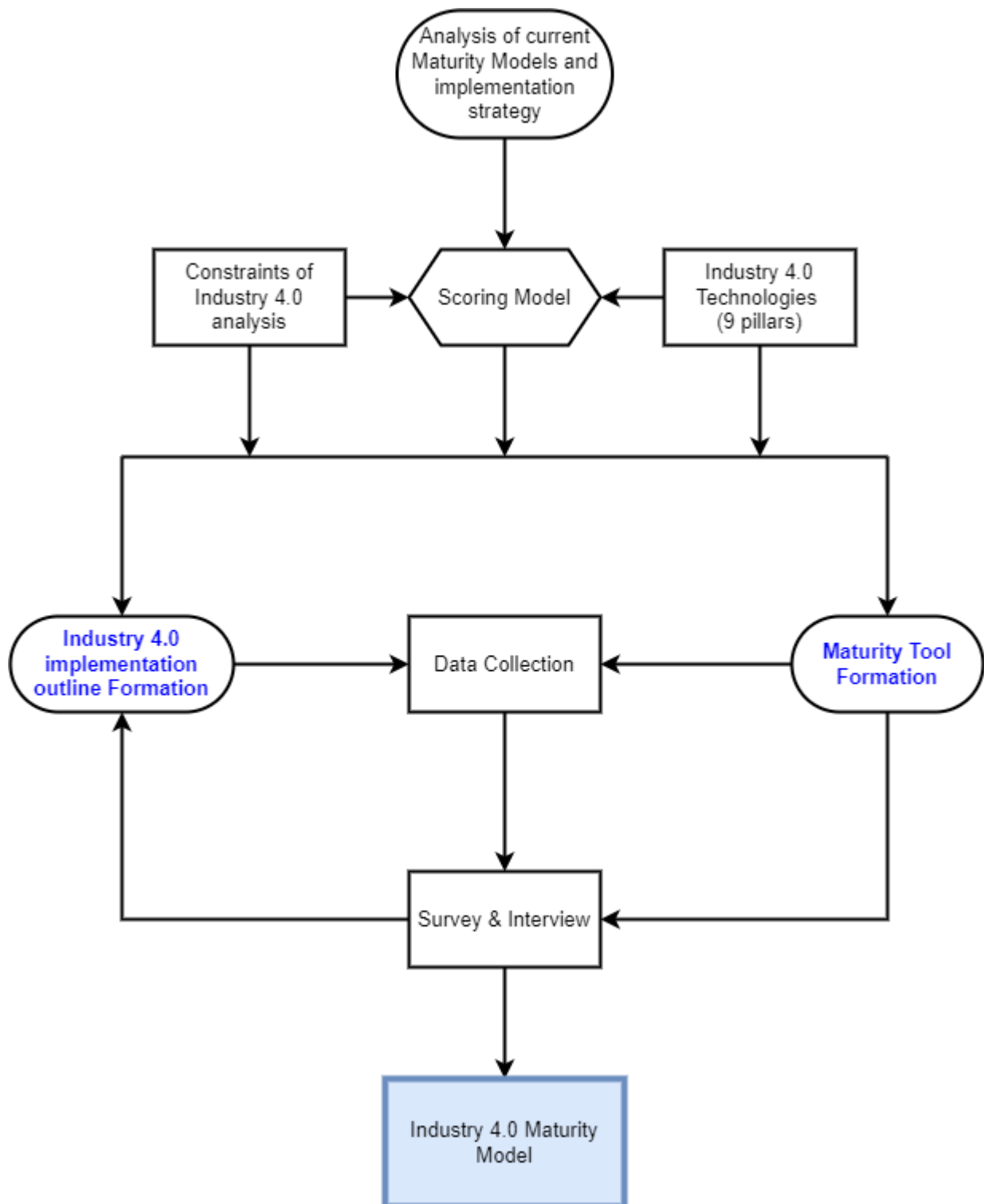
*Figure 26 Structure of the study*

The structure followed in this study is shown in figure 26.

Study and analysis of the maturity models and Industry 4.0 implementation strategies already formed is necessary to appropriately gauge the current insights and

advancements in the field of this study. They provide the basic outline of all the dimensions to consider in an Industry.

Constraints an industry might face during the implementation of Industry 4.0 in India is studied. The data obtained informs about the key areas of the industry that would be challenging to upgrade and serves as one of the bases for the formation of the implementation strategy and maturity model for Industry 4.0.

9 Pillars of Industry 4.0 is studied to get to know about the key technologies associated with Industry 4.0 and will serve as the key technologies to track the implementation of Industry 4.0.

A scoring model is then used to evaluate the current maturity models for comparison with the new tool formed later. This scoring model takes inputs from the analysis of maturity models, industry 4.0 constraints and 9 pillars of Industry 4.0 to shortlist the dimensions for the new tool formed and the implementation strategy.

A survey and interview are conducted to get first-hand information from the industry personnel themselves. The data from this survey is used as an input for the strategy formation and maturity tool formation.

# 4. Data Collection

## 4.1 Scoring Model

A non-weighted scoring model is used to evaluate the present maturity models to identify the gaps and improve upon them. This scoring model also serves as a comparison for evaluating the developed model.

The newly proposed model, to be shown as more suitable for the Indian MSMEs should be evaluated with comparison to the previous models. This scoring model is used as a benchmarking tool for this comparison.

Availability of the tool, consideration given to the nine pillars of industry 4.0, their suitability for manufacturing MSME in India and strategy provided for the implementation are the four key dimensions, scoring of the maturity models are based upon. They cover all the basic areas that determine the usability of an Industry tool, with a focus on India.

**Availability of tool**

Ease of access to the maturity model or tool at the right time is necessary for the evaluation. This dimension is considered to compare and evaluate the availability of the tool with the following justification as shown in Table 2.

| Score | Justification |
|---|---|
| 1 | Only theoretical model |
| 2 | Model with offline tool for self-evaluation |
| 3 | Online tool for self-evaluation |

*Table 2 Scoring Model - Availability of tool*

**Nine pillars of Industry 4.0**

Nine pillars of Industry 4.0 inform us about the key technologies that define Industry 4.0, as explained in section 2.2.1. This dimension is considered, and the scoring is based on the separation of top, middle and low 33.33% of the models' coverage of those nine pillars, as shown in Table 3.

| Score | Justification |
|---|---|
| 1 | Covers 3 dimensions |
| 2 | Covers 6 dimensions |
| 3 | Covers all 9 dimensions |

*Table 3 Scoring Model - Nine pillars of Industry 4.0*

**Suitability for manufacturing MSME in India**

This dimension is considered to gauge a maturity models' usefulness for MSMEs in India. To separate a tool that has no specific relevance to MSME, a tool that is not specific to India and a tool that is for MSMEs in India this is considered as shown in Table 4.

| Score | Justification |
|-------|---------------|
| 1 | General tool with few relevant dimensions |
| 2 | Suitable for manufacturing SMEs |
| 3 | Tool focused on India |

*Table 4 Scoring Model - Suitability for manufacturing MSME in India*

**Strategy for Implementation**

A maturity model informs an organisation about it current level of maturity. If this information is to be useful, an organisation must build upon their current capabilities to achieve the vision of Industry 4.0. For this, a blueprint or strategy is required for the effective implementation of Industry 4.0. So this dimension is considered, as shown in Table 5, to separate out the models which do provide the implementation strategy.

| Score | Justification |
|-------|---------------|
| 1 | No strategy suggested |
| 2 | Strategy implied in literature |
| 3 | Explicit strategy provided |

*Table 5 Scoring Model - Strategy for Implementation*

With the dimensions to be considered shown above and the justification given to the scoring, the following are the scorings given for the maturity models that are considered in the background study.

| 1. Uni-Warwick | |
|----------------|---|
| **Dimension** | **Score** |
| Availability of tool | 2 |

| Nine pillars of Industry 4.0 | 3 |
|---|---|
| Suitability for MSME in India | 2 |
| Strategy for Implementation | 2 |

*Table 6 Uni Warwick - Scoring Model*

This tool is available as an offline tool for evaluation at (Agca, et al., 2017), considering all the nine pillars of industry 4.0 explained in section 2.2.1. This tool is based on a survey that does not consider India, shown in figure 9. So, Table 6 shows the scoring for Uni Warwick tool.

| **2. IMPLUS** | |
|---|---|
| **Dimension** | **Score** |
| Availability of tool | 3 |
| Nine pillars of Industry 4.0 | 3 |
| Suitability for MSME in India | 2 |
| Strategy for Implementation | 3 |

*Table 7 IMPLUS - Scoring Model*

This tool is available as an online self-evaluation at - Industrie 4.0-Readiness-Check (industrie40-readiness.de) and considers all the nine pillars of Industry 4.0 in its evaluation. This tool can be used for SMEs but is not focused on India. Table 7 shows the justified scoring for IMPLUS tool.

| 3. PwC | |
|---|---|
| **Dimension** | **Score** |
| Availability of tool | 3 |
| Nine pillars of Industry 4.0 | 3 |
| Suitability for MSME in India | 2 |
| Strategy for Implementation | 3 |

*Table 8 PwC - Scoring Model*

This tool is also available as a self-evaluation at - Industry 4.0 - Self Assessment (pwc.de) and considers all the nine pillars of Industry 4.0 in its evaluation. This tool can be used by SMEs, but only 21% of the survey. This tool is based on, is from Industrial Manufacturing, as shown in Figure 16. So, the scoring in Table 8 is justified.

| 4. Forrester | |
|---|---|
| **Dimension** | **Score** |
| Availability of tool | 2 |
| Nine pillars of Industry 4.0 | 3 |
| Suitability for MSME in India | 1 |
| Strategy for Implementation | 3 |

*Table 9 Forrester - Scoring Model*

This tool is available for organisations as a Written questionnaire at (Gill & VanBoskirk, 2016) and considers all the nine pillars of Industry 4.0 in its evaluation. This tool is a general business tool usable by all organisations without any particular focus on SMEs or on India. So, Table 9 shows the scoring for Forrester digital maturity model.

## 4.2 Tool Formation

For a successful formation of a maturity tool, one must consider the current work that is already done in the field. With the knowledge of the dimensions and subdimensions already considered by the pioneers, this study filters out the dimensions that are suitable for the model's usage amongst Indian MSMEs. As most of the models that are already present might already cater to SME's

| Models | Dimensions | Sub Dimensions |
|---|---|---|
| Uni Warwick (Agca, et al., 2017) | Products and services | Product customization, Digital features of products, Data-driven services, Level of product data usage, Share of revenue. |
| | Manufacturing and operations | Automation, Machine and operation system integration (M2M), Equipment readiness for Industry 4, Autonomously guided workpieces, Self-optimizing processes, Digital modelling, Operations data collection, Operations data usage, Cloud solution usage, IT and data security. |
| | Strategy and organisation | Degree of strategy implementation, Measurement, Investments, People capabilities, Collaboration, Leadership, Finance. |
| | Supply chain | Inventory control using real-time data management, Supply chain integration, Supply chain visibility, Supply chain flexibility, Lead times. |
| | Business model | 'As a service' business model, Data driven decisions, Real-time tracking, Real-time and automated scheduling, Integrated marketing channels, IT supported business. |
| | Legal considerations | Contracting models, Risk, Data protection, Intellectual property. |

| | | |
|---|---|---|
| IMPLUS | Strategy & organisation | Strategy, Investments, Innovation Management. |
| | Smart Factory | Digital Modelling, Equipment Infrastructure, Data usage, IT systems. |
| | Smart Operations | Cloud usage, IT security, Autonomous processes, Information sharing. |
| | Smart Products | Data analytics in usage phase, ICT add-on functionalities. |
| | Data-driven services | Share of data used, Share of revenues, Data-driven services. |
| | Employees | Skill acquisition, Employee skill sets. |
| PwC (Geissbauer, et al., 2016) | Digital business models and customer access. | |
| | Digitisation of product and service offerings. | |
| | Digitisation and integration of vertical and horizontal value chains. | |
| | Data & Analytics as core capability. | |
| | Agile IT architecture. | |
| | Compliance, security, legal & tax. | |
| | Organisation, employees and digital culture. | |
| Forrester (Gill & VanBoskirk, 2016) | Culture | |
| | Organisation | |
| | Technology | |
| | Insights | |

*Table 10 Maturity models overview*

Table 10 shows all the dimensions and sub-dimensions of the previously explained maturity models of section 2.3. The dimensions – Business model, strategy & organisation, and supply chain of Uni Warwick; strategy & organisation, and employees of IMPLUS; Organisation, employees and digital culture, Digital business models and customer access of PwC; and Culture, and organisation of Forrester is integrated into one

category – Organisation. The dimensions – manufacturing & operations of Uni Warwick; Smart factory & smart operations of IMPLUS; Digitisation and integration of vertical and horizontal value chains of PwC; and Technology of Forrester is integrated into the "Manufacturing & operations" category. The dimensions Products & services of Uni Warwick; Smart Products of IMPLUS; Digitisation of product and service offerings of PwC; and Technology of Forrester is integrated into the "Products" category. And similarly, data-driven usage & protection sub-dimensions of Uni Warwick; Data-driven services dimension of IMPLUS; Data & Analytics as core capability dimension of PwC; and Insight's dimension of Forrester is integrated into the "Data management" category.

According to Harvard Business Review, the four domains of Industry 4.0 are Organisational change capacity, Process, Technology and Data, as explained in section 2.2.2.  The integrated dimensions are in co-relation with these four dimensions. So, the Industry is segmented are four parts to track the upgradation. They are – Organisation, Manufacturing & Operations, Products and Data management.

As explained in section 2.8, factors that drive the implementation of Industry 4.0 are – Current technological capabilities, knowledge about Industry 4.0, organisational mentality towards innovation & upgradation, and usage of technologies. So, sub-dimensions that come under organisation – Investments and organisational strategies are aimed to get insights about organisational culture and the willingness of the industry to innovate and upgrade. As Indian MSMEs lack the knowledge about Industry 4.0, this dimension evaluates the rate of education in the organisation through the usage of strategies dimension.

Indian MSMEs face a technological deficit due to the usage of age-old machinery, as explained in section 2.6. The sub-dimensions that come under the Manufacturing and control dimension measures the automation level in an Industry through the usage of the automation pyramid explained in section 2.2.3. Also, as the technologies used drives the implementation of Industry 4.0, the sub-dimensions also measure the technologies used in the industry in accordance with the "Nine Pillars of Industry 4.0."

The sub-dimensions under the product's dimension aims to measure the level of digital features offered with the product in accordance with Industry 4.0 technology. Also, according to UniWarwick as one of the main features of Industry 4.0 is the ability to produce a batch of size one at the same cost of mass production. The subdimension also measures product customisation.

As explained in section 2.8, cyber security is one of the main challenges faced by Indian MSME. The sub-dimensions under the data management dimension aims to gauge the level of care an organisation is taking towards cybersecurity. And as the management of data and implementation of cybersecurity requires the presence of an IT team in the organisation, the sub-dimensions also measure the architecture of the IT department in the organisation.

## 4.3 Formation of Industry 4.0 implementation outline

Organisations can get to know about their current maturity through the tool proposed. But the data obtained must be put into quality use for an organisation to succeed. The need for an Industry 4.0 implementation strategy comes at this point. This strategy aims to provide a blueprint or a roadmap for the implementation of the Industry 4.0 Strategy so that the data gained from the maturity model is correctly used.

Knowledge about the facilities and resources of an organisation is vital for innovation (OECD, 2018). So, the starting point of this outline is the maturity model itself. Prioritisation of the pilot projects is very important in an industry as it builds an upgradation mindset and increases the success rate of these projects (Rodriguez-Nieto, 2016).

Prioritisation of projects is a necessity as there is a deficiency of funding. Projects that are immediately beneficial for the organisation must be favoured first to reap the benefits quickly. Funding is one of the main problems that plague the Indian MSMEs. There is about ₹87.7 trillion equity and debt demand by Indian MSMEs (IFC, 2018). This problem of funding is more evident in micro-enterprises because of their financial size (Biswas, 2014). So, they must have a pre-planned funding strategy for their upgradation.

Lack of skilled labour is also one of the problems faced by Indian MSMEs (Chakraborty, 2016). As skilled labour is a necessity for the operation of machines, this needs to be addressed by any organisation before going about projects related to the upgradation of their Industry.

Pilot projects are the pioneer projects of upgradation in the industry. They show the transition of upgradation from strategy to implementation. These projects show the commitment mentality of the organisation towards the implementation of Industry 4.0.

The continuous evolution of technology in an Industry is very much necessary for them to stay competently in business. Although an organisation might have the upper hand in the market, without continuous improvements, they will lose their market share, as in the case of Intel as they failed to implement the new 7nm process technology that their competitors are already using (Gwennap, 2021).

## 4.4 Survey

This survey is done to obtain data regarding the challenges faced by industries during the upgradation. This survey also has sections derived from the tool dimensions, and questions are formed to gauge the maturity of the surveyed industries.

This survey is semi-structured with both open-ended and close-ended questions. The closed-ended questions with predetermined answers will help in the identification of the strategies that are formed and current industry capabilities. The open-ended question is to obtain answers which might not be predicted in the literature. The questions in the survey, shown in Table 11, are categorised into five sections. First, four sections are the dimensions of the new tool – Organisation, Manufacturing and Control, Products and Data

Management. The last section is the suggestions section for the feedback regarding their experience from the upgradation process.

| Question | (Scoring) Expected answer or MCQ |
|---|---|
| **Organisation** ||
| **1.** Name of the organisation (Not Mandatory) | |
| **2.** Geographical location | India<br><br>Other (user specified) |
| **3.** Your position in your organisation | Shopfloor<br><br>Middle Management<br><br>Top management |
| **4.** Approximate Size of your company | 0 - 25 employees<br><br>25 - 50 employees<br><br>50 - 75 employees<br><br>More than 75 employees |
| **5.** Approximate yearly revenue | Upto ₹ 1 Crore<br><br>₹1 Crore - ₹ 5 Crore<br><br>₹ 5 Crore - ₹ 50 Crore<br><br>₹ 50 Crore - ₹ 250 Crore |
| **6.** IT integration | (1) No IT systems<br><br>(2) Main parts of the business are supported by IT systems<br><br>(3) IT supports most processes<br><br>(4) Complete IT integration |
| **7.** Do you have an Industry 4.0 implementation strategy?<br>**8.** Do you have a digital supply chain management strategy?<br>**9.** Do you have a employee education strategy? | (1) No<br><br><br>(2) Planned<br><br><br>(3) In implementation |

| | |
|---|---|
| **10.** Has your organisation invested in new technology?<br>**11.** Do you have a digital marketing strategy? | (4) Already implemented |
| **Manufacturing & Control** | |
| **12.** What is the level of Automation in your organisation? | (1) No automation.<br><br>(2.5) Some manufacturing processes are automated.<br><br>(4) Complete process automation |
| **13.** What best describes the machines in your organisation? | (1) Controllers are used to control machines.<br><br>(2) Along with controllers, all the systems or equipment in the process are linked to each other.<br><br>(3) The data from these machines are also used in tracking the movement of goods.<br><br>(4) These machine data are integrated with business processes (E.g., Usage of ERP systems). |
| **14.** What technologies do you use in your organisation? (Tick all) | CAD (Computer Aided Drawing).<br><br>3D printing.<br><br>Augmented Reality (AR).<br><br>Cloud based services.<br><br>Autonomous robots (E.g., Line follower robots).<br><br>Supply Chain Management Software (Eg. SAP SCM)<br><br>Industrial IOT (Eg. RFID trackers) |
| **Products** | |
| **15.** What are the features of your products produced? | (1) Product shows only physical value.<br><br>(2) Products also hold intellectual property value.<br><br>(3) Products are integrated with some digital features (E.g., RFID Tags).<br><br>(4) Data driven features are integrated with products (E.g., An app to go with your product to increase its value) |

| | |
|---|---|
| **16.** How is your production capabilities? (Product Customisation) | (1) Mass production with no product customisation. <br><br>(2) Large production batches with batch customisation. <br><br>(3) Smaller batches with customisation. <br><br>(4) Production fully customisable - batch of size 1 can be produced at the same cost of mass production. |
| **Data Management** | |
| **17.** How is your IT Department? | (1) No IT department. <br><br>(2) Outsourced IT department. <br><br>(3) In house IT department. <br><br>(4) IT departments for each area of business - Management, Manufacturing, Sales... |
| **18.** How is process data (Data collected during manufacturing) collected and used in your organisation?. | (1) No data is collected during manufacturing. <br><br>(2) Data collected, but not used. <br><br>(3) Less than 50% of data collected is used. <br><br>(4) More than 50% of data collected is used. |
| **19.** Do you have cybersecurity protocols in your organisation? | (1) No cybersecurity protocols. <br><br>(2) Cybersecurity protocols planned. <br><br>(3) Cybersecurity protocols in implementation. <br><br>(4) Cybersecurity protocols implemented. |
| **Suggestions** | |
| **20.** What aspects of an Industry do you find tough to upgrade and hard to overcome? | Infrastructure of an Industry. <br><br>Existing technology. <br><br>Acquiring funds for upgradation. <br><br>Marketing and branding. <br><br>Employees. <br><br>IT department. <br><br>Legal aspects. <br><br>Usage of new software (E.g., SAP-ERP). <br><br>Introduction of data analytics. |

| | |
|---|---|
| | Supply Chain management. Other?.. |
| **21.** Do you wish to disclose your data (Name, organisation & email-id) as a reference for this research? | Yes. No. |

*Table 11 Survey*

**Organisation:** Question about the geographical location is used to sort the responses and consider only the ones based in India. As personnel in the different levels of management would know the organisation from their own perspective, the position responder holds in the organisation is considered to know the diversity of the responders. The size of the company and its approximate revenue is considered for sorting the responders into micro, small and medium scale industries based on Table 1.

IT integration into the business is the main motto behind the digital transformation of Industry 4.0. The level of IT integration is judged through a closed-ended question. No, IT integration is given a score of 1, and three successive IT upgradations till complete IT integration are given a score of 2,3 and 4. Further, the outlook of the organisation is judged by their preparedness towards Industry 4.0, digital supply chain, employee education, digital marketing and new technology. No strategy is given a score of 1, and three successive scorings – 2,3 and 4 are given for the planning, implementation and implemented parts of the strategy.

**Manufacturing & Control:** The level of automation in an organisation is judged primarily with the closed-ended question & response (Agca, et al., 2017). Industries with no automation are given a score of 1, and Industries with complete process automation is given a score of 4. Intermediate industries where some processes are automated are given a score of 2.5, the middle score between 1 and 4.

The automation pyramid explained in section 2.3.3 is used to further judge an organisation based on its mechanisation level. The final process level – 5 is considered to be the "mature Industry 4.0 standard" and is given 4 points. The successive questions that follow are in concurrence with the hierarchy of the automation Pyramid and are given 3,2 and 1 scores.

Nine pillars of Industry 4.0 explained in section 2.2.1 are used as the basis to gauge the technologies used by an organisation. Although there are nine pillars, only seven are considered in question 14. The remaining two technologies – Horizontal & vertical system integration and Cybersecurity are considered in questions 6 and 19, respectively.

**Products:** To examine the progress of digital transformation or Industry 4.0 under the products dimension, two questions are considered. According to the constraints in Industry 4.0 Implementation explained in section 2.6, Indian MSMEs are plagued with

poor infrastructure and outdated technology. Question about features of the product aims to get an insight about the technology used. Integration of data-driven with the product is considered Industry 4.0 mature according to UniWarwick and is given a score of 4. Further questions down the hierarchy till the point where the product produced shows only the physical value is given a score of 3,2 and 1. Question about product customisation aims to get information about the production infrastructure of an organisation. If the production capacity of an organisation can be such that even a batch of size one can be made at the same cost of mass manufacturing, then it is said to be industry 4.0 mature according to UniWarwick, and a score of 4 is given. Similarly, as shown in Table 11, scoring of 3,2 and 1 is given hierarchically for the responses.

**Data Management:** As explained before, IT integration into the business processes is one of the key elements of Industry 4.0. For this integration, having an IT department is very important. Question 17 judges the organisation based on the IT department they have. An organisation with no IT department scores 1, and as shown in table 11, successive scores of 2,3 and 4 are given.

Data collected during manufacturing should be put into use to optimise the production process as well as make decisions. The extent to which this data is collected and used is judged under question 18. If an industry uses more than 50% of collected process data, then it is considered to be an "expert" in Industry 4.0 according to UniWarwick and is awarded a score of 4. Similarly, a score of 3,2 and 1 is given to organisations where less than 50% of data is used, data not used, and no data is collected, respectively.

Cybersecurity is one of the nine pillars of Industry 4.0, as explained in section 2.2.1. Data collected must be stored and transmitted securely. So, question 19 aims to get information on the cybersecurity protocols present in an organisation. Organisations with no cybersecurity protocols are given a score of 1, and successive advances in implementation, as shown in Table 11, are given a score of 2,3 and 4.

**Suggestion:** There are many key areas of the industry where the upgradation of Industry 4.0 will face resistance. Question 20 aims to get to know about these areas by asking an open-ended question. No weightage or scoring is given to this section as this section is used to strengthen the strategy and the proposed tool.

## 4.5 Interview

Through personal contacts, an Industrialist was selected for Interviewing. The details of the interviewee and the industry are provided in Table 12

| Interviewing platform | Skype |
|---|---|
| **Duration** | 45 mins |
| **Name** | Sudhindra HS |

| Organisation | Hejjaji Engineers & Fabricators (HE & F) |
|---|---|
| **Designation** | Managing Partner |
| **Annual Turnover** | ₹ 100,000,000 |
| **Industry Type** | Small scale enterprise |
| **Industry age** | 30 years |
| **Industry Location** | Bengaluru, India |

*Table 12 Interview details*

The interviewee is an experienced industrialist. The industry he works in has experience in manufacturing equipment such as air preheaters, oil storage tanks and vacuum impregnation chambers. The purpose of conducting this interview is to gain first-hand information based on experience for this study. A set of preformed open-ended questions are asked.

**What are the main parts of an Industry to consider during upgradation?**
Different parts of an Industry require separate attention by the management personnel during the upgradation. This question aims to gain knowledge about how MSMEs classify the parts of their industry during the upgradation process.

**Have you recently upgraded any machines or processes in your Industry?**
**Why did you carry out this upgradation?**
These questions aim to get some insights into the upgradation process that has taken place in the industry and their experience with the upgradation. Also, they aim to get information about the benefits of the upgradation and what can improve in an organisation after the upgradation.

**What are the challenges you encountered during this upgradation?**

There are many resistance industries face during upgradation. Constraints of Industry 4.0 implementation is already explained in section 2.6. This question aims to bridge the gap between the literature data and what is happening in an Industry.

**What is the marketing strategy in your organisation?**
**What is the supply chain strategy in your organisation?**
These questions aim to get information about the extent of digitalisation happening in an Indian MSME. Indian industries fall behind in marketing and access to global markets according to constraints of Industry 4.0, as explained in section 2.6. Information about their way of marketing in an MSME is required to gauge where industries might be going wrong, and the supply chain strategy of an organisation tells the study why Indian MSMEs are not competitive enough to tackle foreign markets.

**How is product data collected and used?**
Data analytics can boost an industry's productivity and production quality, as explained in section 2.5. The information obtained through this question helps to understand if an industry is exploiting this competitive advantage if not, why the data analytics is not implemented in the organisation.

**What are the digital features of your products, and to what extent is data integrated into your product?**
Extra features in the form of digital technologies integrated into a product will increase the value of the product and will give the industry a competitive advantage compared to other industries that manufacture similar products. This question aims to get information about the presence of these digital features in the products of manufacturing MSMEs.

# 5. Results and Discussion

## 5.1 Readiness Evaluation Tool

The proposed tool contains two parts that provide a complete solution for manufacturing MSMEs considering Industry 4.0 upgradation. While the maturity model educates the management personnel about the capabilities of the organisation with respect to Industry 4.0, the implementation outline provides them with a basic framework on how to go about the successful upgradation to Industry 4.0.
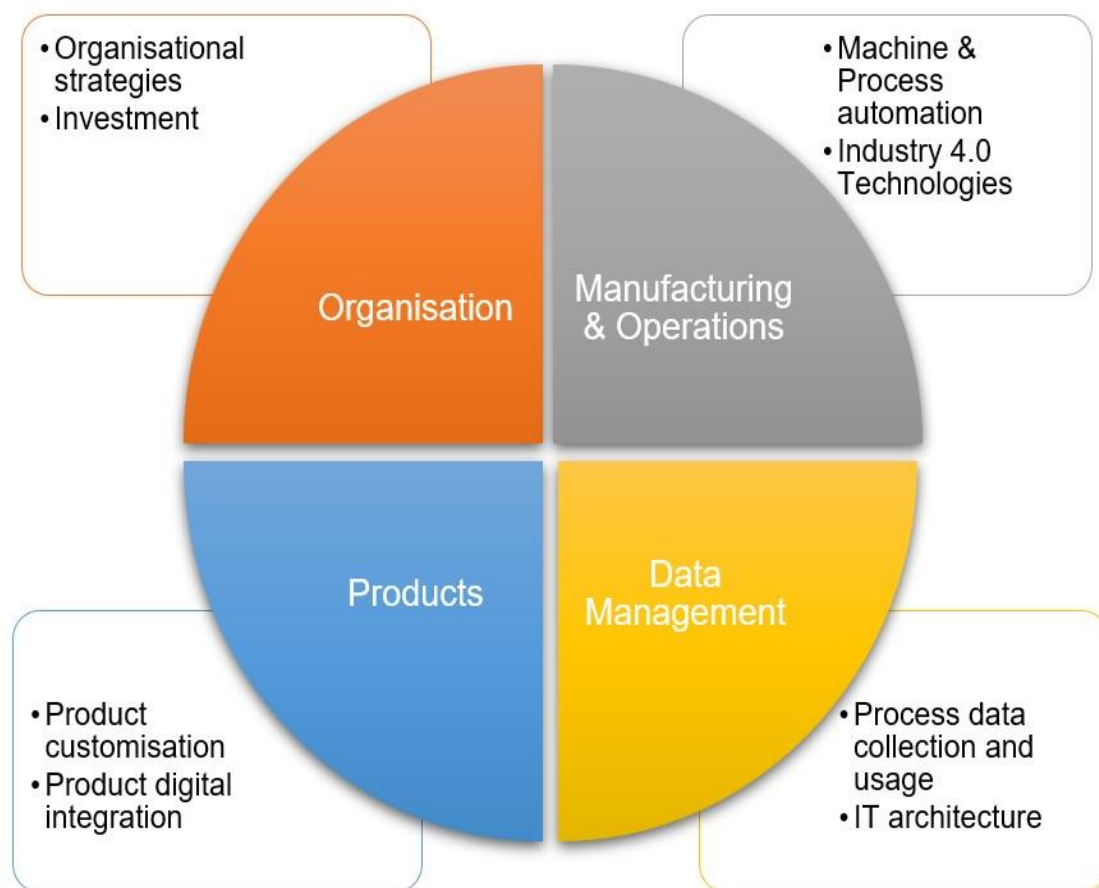
### 5.1.1 Maturity Model

*Figure 27 Industry 4.0 dimensions and subdimensions of the new proposed model*

The dimensions and subdimensions of the new proposed model are depicted in figure 27.

**Organisation:**

Most MSMEs in India are plagued with old equipment and poor infrastructure, as explained in section 2.6. This requires planning and strategy formation, so the mindset of the top management personnel is important and is known under this dimension.

MSMEs in India suffer from poor marketing. This poor performance of these organisations degrades still more with the introduction of foreign competitors. Moreover, psychological facts such as the provenance paradox make marketing even more difficult. So, a marketing strategy is required to tackle these problems, which is gauged under this dimension.

According to the Forrester model explained in section 2.3.3, employees are the majority stakeholders. So, employee education to adapt and change according to this upgradation is necessary, which is also judged under this dimension.

**Manufacturing and Operations:**

The automation pyramid explained in section 2.2.3 serves as the base to judge the maturity under this dimension. Here if an organisation is at the top or level 5 of this automation pyramid, then it is considered to be Industry 4.0 mature for this dimension. Furthermore, the technologies used in the organisation, in accordance with the nine pillars, are also gauged under this dimension.

**Products:**

As explained by the maturity models in section 2.3, it is evident that to distinguish a product from its competitors, digital features and "add on" must be offered to the customers. The more digital features added to a product will increase the functionality of the product. That is, if a prospective customer who wants to buy a weighing scale goes to a market and sees two products, which have similar quality & pricing, but one offers additional data features such as measuring the body composition through the weighing machine itself, they feel more inclined to buy the product which offers more value through the addition of these digital features. Additionally, the customisability of the product is also a strategy to distinguish a product from its competitors. Product customisation can result in an increase in customer satisfaction, positive marketing and product margins (Burns, 2020). So, this dimension judges the level of digital features a product offers and the product customisability of an organisation.

**Data Management:**

The data collected during various production processes must be processed correctly and implemented in a useful way. For this, an IT team is necessary having appropriate cybersecurity protocols. So, the presence of an IT team, level of data usage and the cybersecurity protocol are gauged under this dimension.

| Description (x) | Score |
|---|---|
| Learner | 1=x<2 |
| Change Maker | 2=x<3 |
| Intermediate | 3=x<4 |
| Mature | x=4 |

*Table 13 Industry maturity levels based on scoring*

These dimensions are evaluated in the form of a survey, and Industries are sorted into four categories based on their level of maturity, as shown in Table 13

**Mature:**

A Mature organisation will have already implemented their Industry 4.0, digital SCM, employee education, digital marketing strategies and would have already invested in Industry 4.0 technology. They will also have complete process automation with interconnected machines supporting business processes. They will have data-driven features imbibed in their product with complete product customisation available. They will have cyber security protocols with IT departments for each area of business, with over 50% of data being used.

**Intermediates:**

Intermediate organisations' strategies would be in the implementation stage. They will have some level of automation with interconnected machines providing real-time data. They will have products with some digital features with product customisation in smaller batches. They will have in house IT department with less than 50% of data collected being used.

**Change Makers:**

Change maker organisations will be planning the strategies. They will have a few machines automated with integrated machinery. Their products hold only the intellectual property value and have product customisation in large batches. They will have outsourced IT departments with process data being collected but not used.

**Learners:**

Learner organisations will have no strategies. They will have no automation, with basic controllers used to control machinery. Their product would show only physical value with no customisation options available They will have no IT department with no data being collected during the manufacturing process.

## 5.1.2 Industry 4.0 implementation outline



```
┌─────────────────┐
│ Current         │  • Will inform an
│ maturity level  │    organisation about its
│ analysis        │    strengths and
└─────────────────┘    weaknesses.

        ┌─────────────────┐
        │ Prioritisation  │  •  Prioritisation of pilot projects
        │ & Funding       │  •  Formation of funding
        └─────────────────┘     strategy

                ┌─────────────────┐
                │ Employee        │  • Employee skill
                │ education       │    upgradation.
                └─────────────────┘  • Distribution of
                                       responsibilities

                        ┌─────────────────┐
                        │ Create pilot    │  • Projects catering to the gap
                        │ projects        │    found.
                        └─────────────────┘  • Provides experience

                                ┌─────────────────┐  • Maturity
                                │ Continuous      │    should not be
                                │ evolution to    │    considered as
                                │ keep up with    │    a foxed state.
                                │ technology      │  • Market
                                └─────────────────┘    volatility calls
                                                        for continuous
                                                        innovation.
```
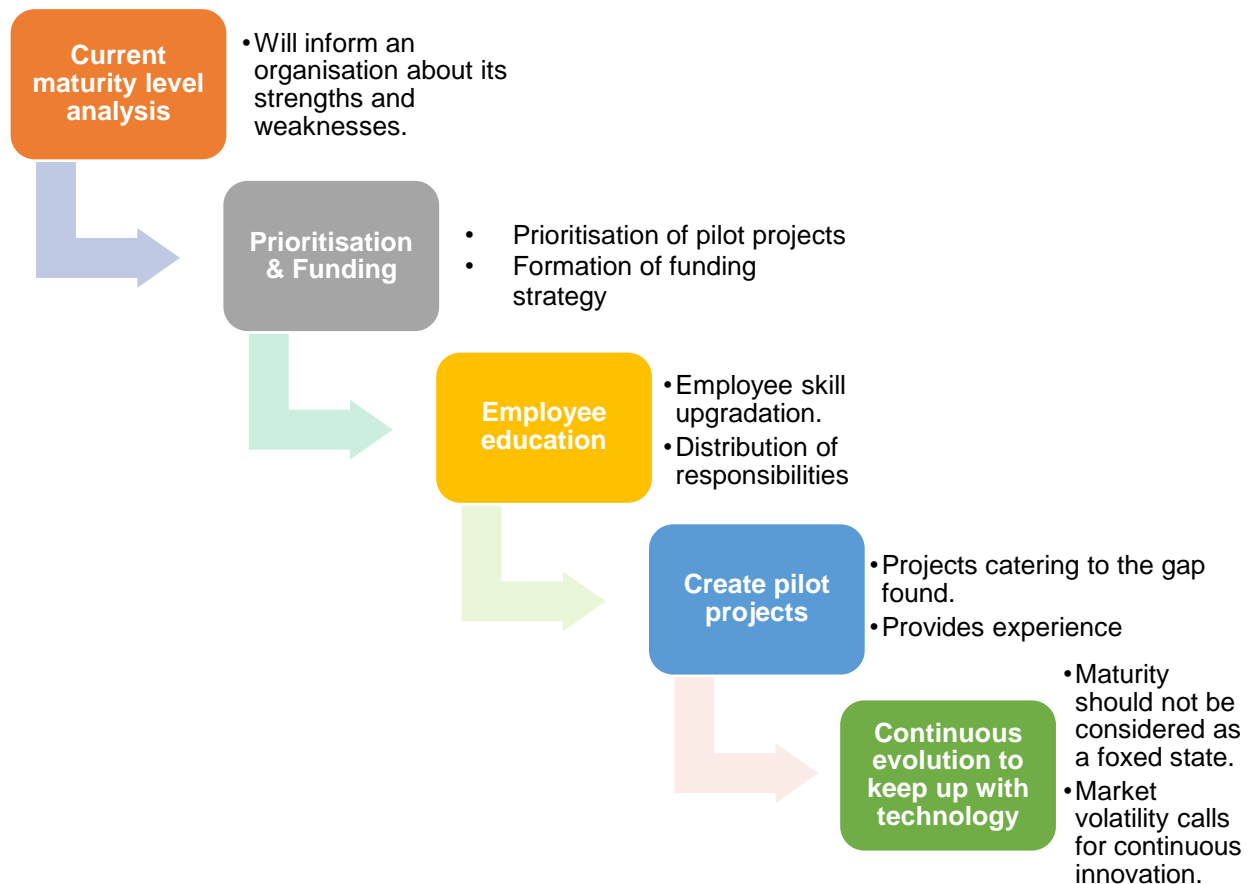
*Figure 28 Industry 4.0 Implementation strategy*

### 1.  Current maturity level analysis

Knowledge about the capability of an organisation informs them about their strengths and weaknesses to help them move further (Gill & VanBoskirk, 2016). This can help identify the areas of the industries an organisation must consider during their upgradation process. So, analysis of the current maturity level is necessary to move further and form strategies for pilot projects.

### 2.  Prioritisation & Funding Strategy

After identification of the gap areas in an Industry, organisations must prioritise the pilot projects according to the immediate needs of an Industry and its vision. That is if an Industry at level one maturity is already forming strategies to upgrade and they get an

order for multiple small batches of different products, it is more beneficial for them to prioritise and upgrade their manufacturing and production capabilities rather than improving digital features of their product.

Funding is required to fuel this upgradation process. So, industries must plan a financial strategy before the upgradation. According to the prioritised project where funding is required, MSMEs can make use of government schemes such as international co-operation scheme, pradhan mantri mudra yojana, marketing assistance scheme or credit guarantee scheme (Ministry of MSME, 2015), which offer collateral-free loans, marketing loans or bring in an investor and give up a part of their equity for funding.

### 3. Employee education

The employee skill level and education are necessary to keep up with modernized technology. Moreover, they are the stakeholders for the industry's upgradation. With more automated and interconnected systems coming up, more requirement of skilled workers is there to meet the demand.

Accountability is a necessary strategy to solve the weaknesses of an organisation. Even with the knowledge of these weaknesses, many organisations fail to take measures to improve them as specific responsibilities for roles accountable for the challenges faced are not properly defined. So, distribution of responsibilities and challenges is necessary to ensure smooth development. (Gill & VanBoskirk, 2016).

### 4. Create pilot projects

Pilot projects or new initiatives should be used as a testing ground to prove the value of upgradation projects. A particular challenge or a gap needs to be focused on in a project while emphasizing the holistic Industry 4.0 approach. Although not every project would be successful, they would provide valuable experience about multidisciplinary working culture inclusive of customers and technology providers. (Geissbauer, et al., 2016)

### 5. Continuous evolution to keep up with technology

Due to the volatility of the market-driven by continuous developments and advancements in technology, the "Digital Maturity" must be viewed as a continuous endeavour rather than a constant state. Organisations must evaluate their projects considering return on efforts, both financial and non-financial. With this strategy and attitude, an organisation can gradually improve and grow. (Gill & VanBoskirk, 2016).

## 5.1.3 Comparison

The new tool proposed is compared with the tools from the literature by using a simple non-weighted scoring model.

| New proposed tool | |
|---|---|
| **Dimension** | **Score** |
| Availability of tool | 3 |
| Nine pillars of Industry 4.0 | 3 |
| Suitability for MSME in India | 3 |
| Strategy for Implementation | 3 |

*Table 14 New proposed tool - scoring model*

This tool focuses on the manufacturing MSMEs in India and consists of a maturity model & an outline for implementation of Industry 4.0. This tool also considers all the nine pillars of Industry 4.0, as explained in section 4.4. This tool is available to users online through the google forms platform. Considering scoring justifications from Table 2 to 5, Table 13 shows the scoring of the new proposed tool.

| **Industry 4.0 upgradation tool** | **Total Score** |
|---|---|
| Uni Warwick | 9 |
| IMPLUS | 11 |
| PwC | 11 |
| Forrester | 8 |
| **New proposed tool** | **12** |

*Table 15 Scorings of different tools*

Table 14 shows the scorings of the tools considered in the literature against the scoring of the new proposed tool. It is evident that the newly formed tool is better suited for Indian MSMEs compared to the other tools in the market.

## 5.2 Survey Results

This study is focused on India. So, to have credible and usable data, all the survey responses must be from India. Survey question 2 used in this study gives insight into the geographical location of the responders.
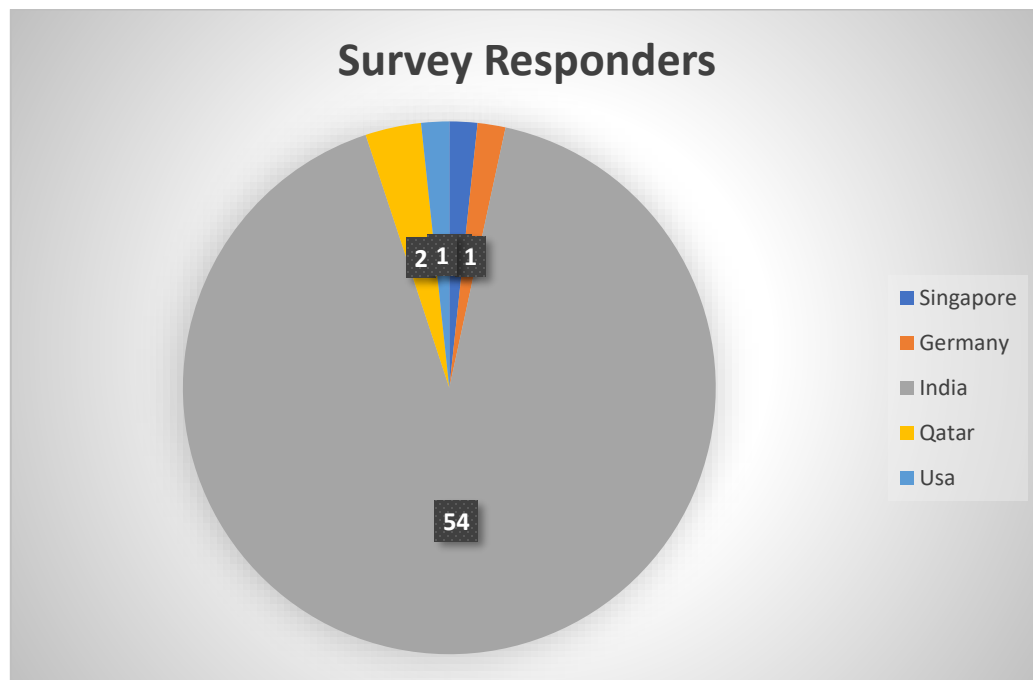
## 5.2.1 Survey Statistics



*Figure 29 Geographical Location of survey responders*

Fifty-nine responses were obtained during this survey. Amongst them, 91.5% or 54 of the responses were from India, as shown in figure 29. Germany, Qatar, USA and Singapore made up the remaining five responses. So, only the fifty-four responses from India are considered for further evaluation in this survey.

This study has a diverse set of responders from various backgrounds in an Industry, as shown in figure 30.
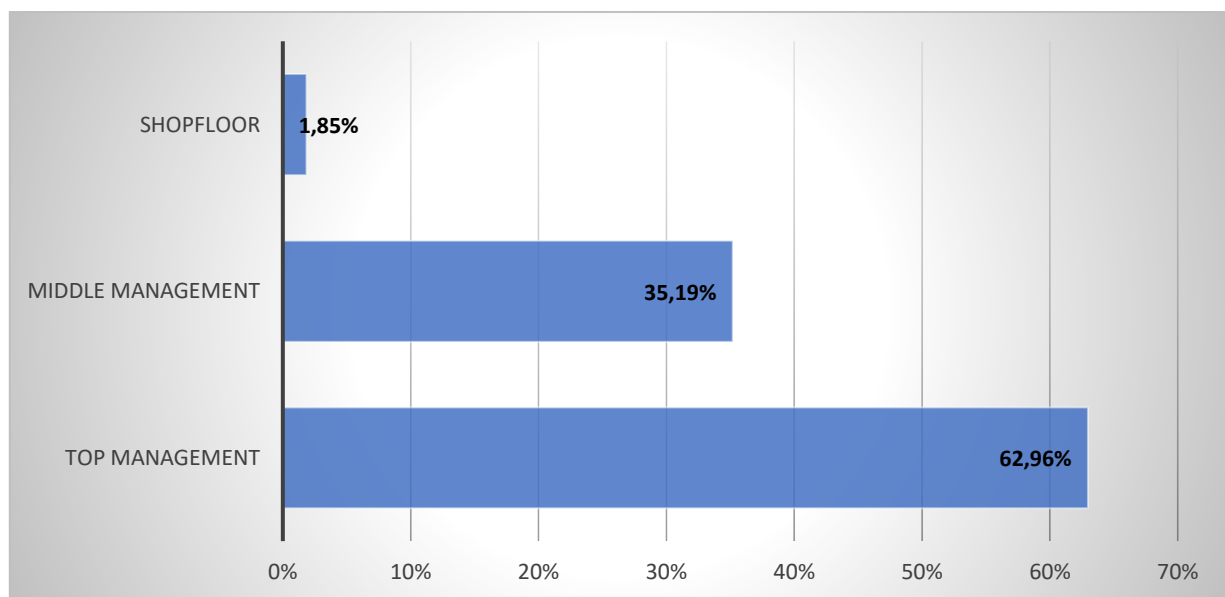


*Figure 30 Positions of survey responders*

Thirty-four of the responses received was filled by the top management executives in the industry. Nineteen and one response were filled by middle management executives and shop floor workers respectively. Although shopfloor workers might have more practical and hands-on knowledge about the working of machines, they would have little knowledge about the top management functions like the finances, strategies formed and implemented. So, top and middle management executives have higher knowledge of the overall functions of the industry comparatively. As top management executives make up the most response, the survey credibility is maintained.

As explained previously, there are three types of enterprises that come under MSME. However, the Indian Industry market has more micro-enterprises and is skewed towards them. In order to have a tool that is suitable for all the types of industries, it is required to have responses from all.
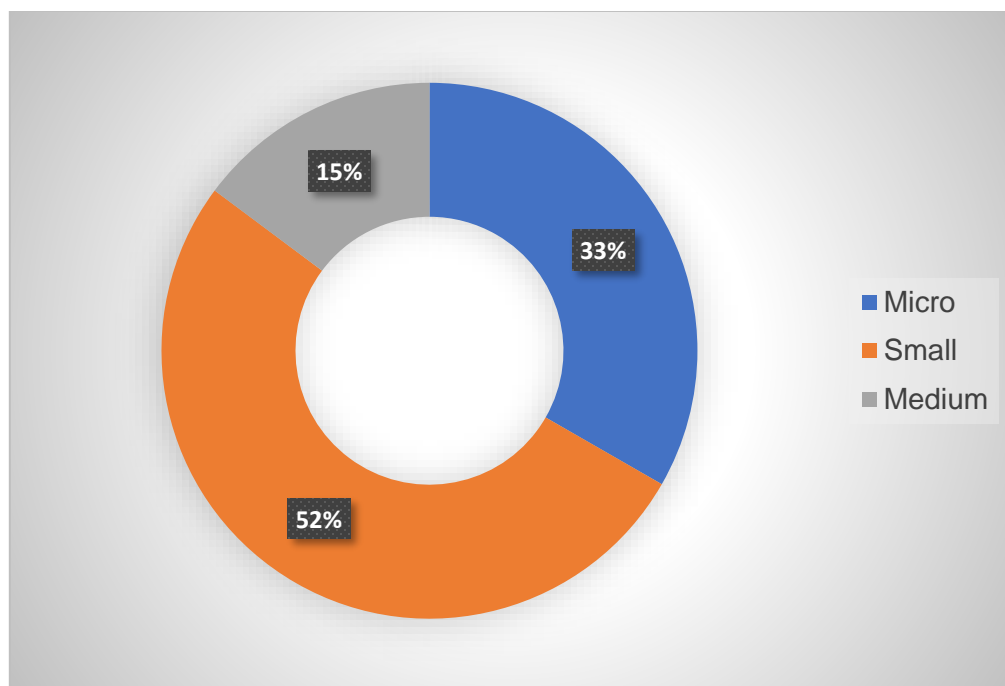


*Figure 31 Industry type of survey responders*

The majority of the responders worked at small enterprises, whereas 33% and 15% of the responders were working at Micro and medium enterprises, respectively as shown in figure 31. Even though there are more micro industries in India, the reason there are more responders from small enterprises might be because many responders in this survey were contacted through networking of people who were already contacted for the purpose of this survey, who were the majority of people from small enterprises.

### 5.2.2 Technologies used by responders

Technologies used in an Industry is the heart of Industry 4.0. There are nine key technologies that surround Industry 4.0 upgradation according to the nine pillars of Industry 4.0 as explained in section 2.2.1.
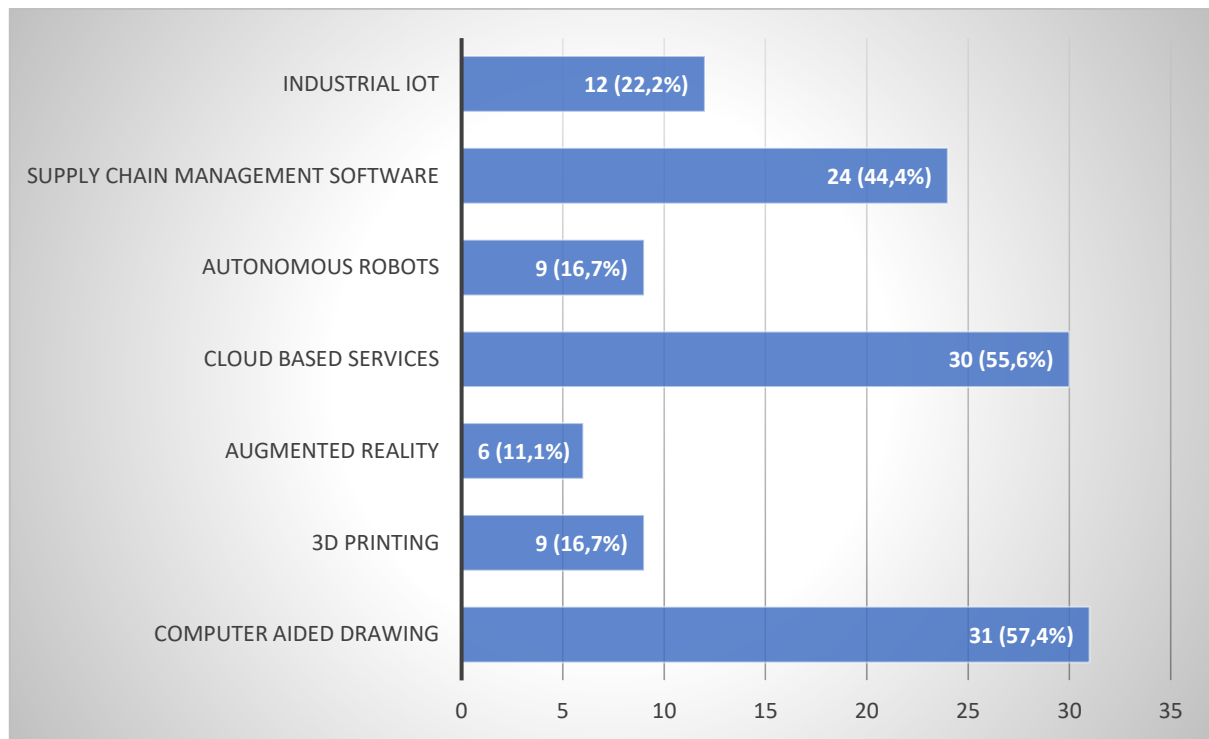
*Figure 32 Technologies used by Indian MSMEs*

Figure 32 shows the technologies used by Indian MSMEs according to the survey. This evidently shows that majority of the MSMEs in India are already using Computer Aided Drawing technology & cloud-based services in their manufacturing, and few of the Indian MSMEs have implemented supply chain management software. But there is no widespread usage of these technologies yet. Also, where Indian MSMEs fail is in the implementation of technologies such as Industrial IOT, autonomous robots, augmented reality and 3D printing. Industries must prioritise according to the needs and focus on these technologies.

### 5.2.3 Maturity Scoring

The questions asked in this survey is separated into four categories that represent the part of an Industry. Shown in Table 13, the scoring represents four levels of maturity an Industry can possess according to their current capabilities.

The scoring is given such that an Industry that has no planning to implement industry 4.0 or has undergone any upgradation is scored 1, and as they have got to learn a lot regarding this upgradation, so they are called learners. Industries with scoring between 1 to 2 will have just planned their upgradation, so they are called change makers. Industries with scoring between 2 to 3 will have started with their implementation and invested in new technologies, so they are called Intermediates. And industries with a score of 4 are Industry 4.0 mature organisations. They will have completed their implementation of strategies and would have their machines & production capabilities upgraded to meet the standards of Industry 4.0.
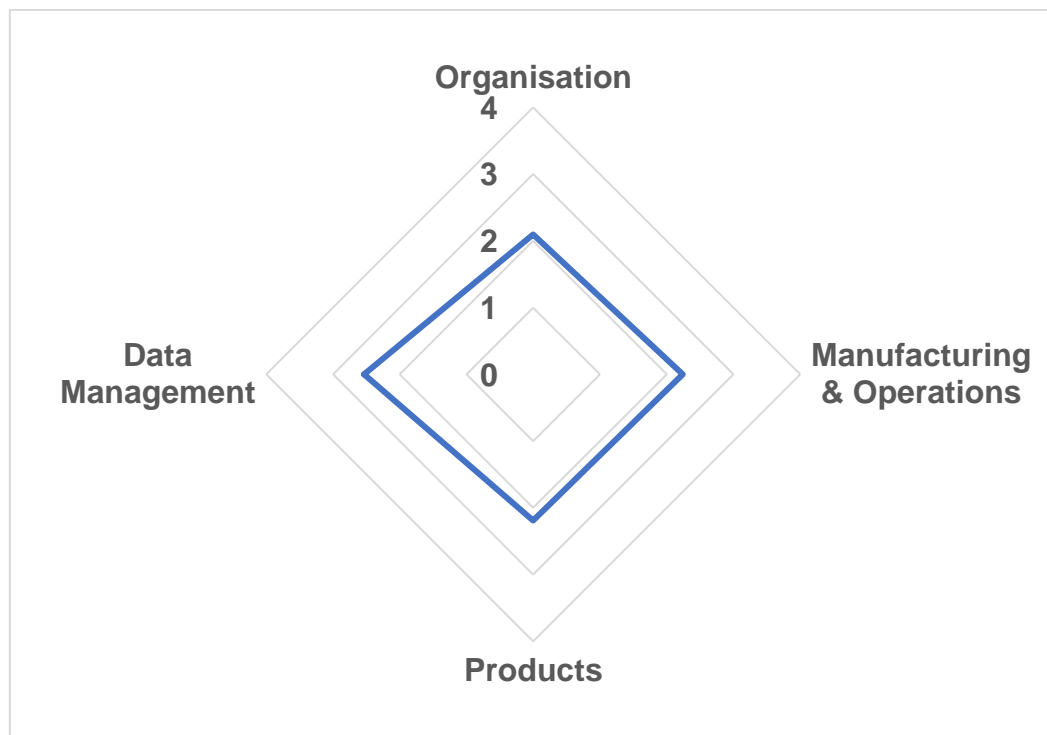
*Figure 33 Benchmarking Graph*

The fifty-four industries considered in this survey are scored considering each of the domains. Under each dimension, the surveyed Industries are analysed, and average scores are evaluated to obtain the benchmarking line shown in blue colour in figure 33. This blue line represents the average level of maturity Indian MSME possess on the graph. The average maturity the surveyed organisations possess is 2.23.

Any Industry after their evaluation in this tool would have their maturity plotted out on the graph, and they can compare where they stand with respect to their competitors visually. This will help them to know which of the areas of the industry they need to concentrate more on for their upgradation to remain competent in the business.

### 5.2.4 Barriers in Industry 4.0 Implementation

When these industries upgraded their technology, they faced many setbacks. These setbacks will educate an industry on which factors they need to focus more on when they are upgrading.
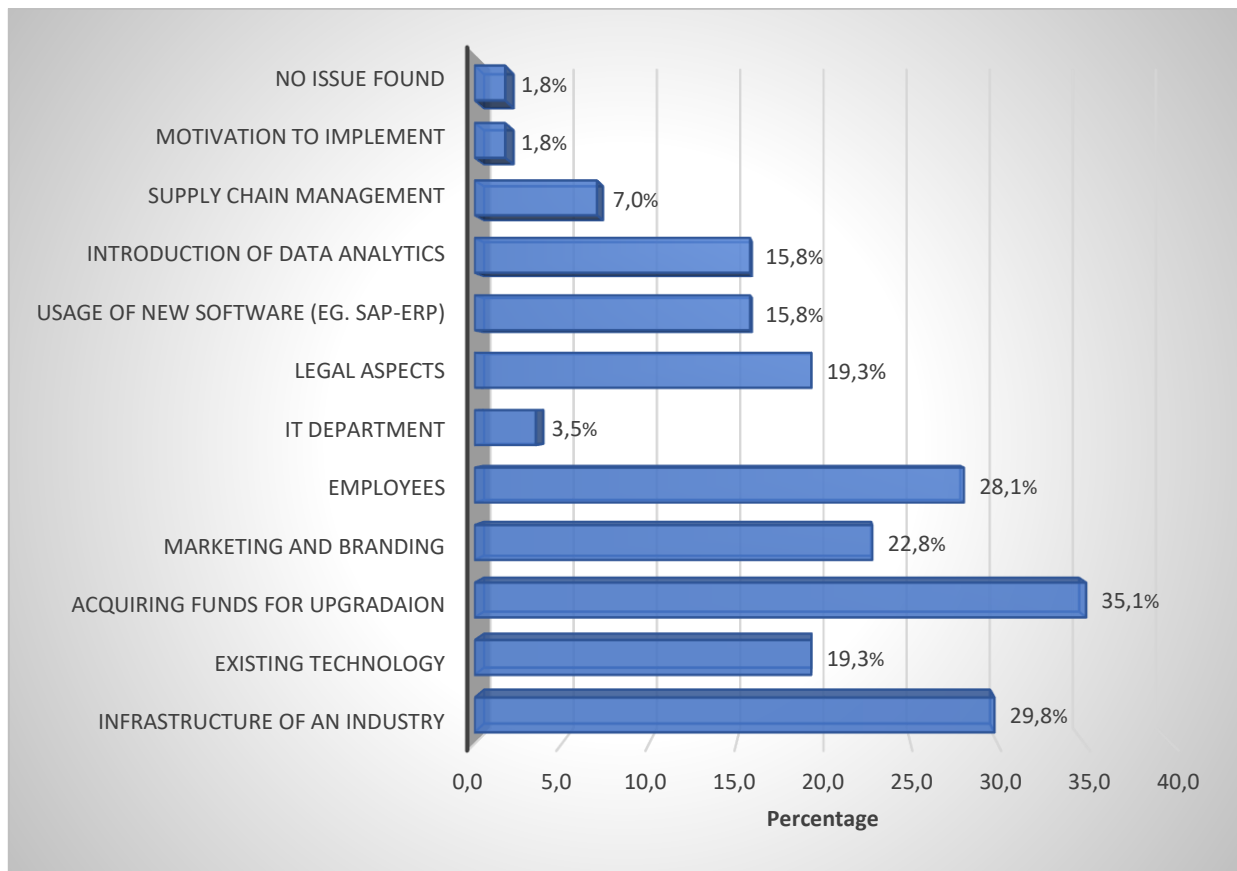
*Figure 34 Barriers in Industry 4.0 implementation*

Acquiring funds for the upgradation was the most common problem faced by Indian MSMEs, with 35.1% of the responders facing resistance in that area. This validates the necessity of the funding strategy required, as explained in section 4.3 during the formation of the Industry 4.0 implementation outline. Resistance was faced by 29.8% of responders while upgrading the infrastructure and 19.3% while upgrading their technology. This might be due to the fact that India has more micro-enterprises but very few small and medium enterprises. And as infrastructure & technological upgradation is an expensive ordeal, many micro-enterprises might not have access to funds to fuel these upgrades. 28.1% of the organisations faced problems with employee upgradation. This might be because there is a shortage of skilled labour in India. Indian MSMEs also faced problems in legal are data analytics and usage of new software. Few industries faced problems related to the IT department. Lack of knowledge of the benefits of Industry 4.0 might have prompted the motivation to implement a reply.

## 5.3 Interview Results

This semi-structured interview provides valuable insights into the upgradation processes that happen in an Indian MSME. This interview also provided a platform for the interviewee to express his thoughts rather than fill out a pre-determined set of multiple-choice questions.

The first question was about different parts of an Industry to consider while upgrading. With his experience running a small-scale mechanical industry, the interviewee explained three segments of the industry – finance, machinery, manpower. The reason why he considered these three segments was because his assessment is that for any upgradation to be implemented, there is a need for financing; machinery play an important role to enhance the production capabilities to meet the demand, and manpower to complement the machinery is very important as without skilled people to run the machines, there is no productivity in the industry.

The next question was about the recent upgradation in the interviewee's industry and the reason for the upgradation. The interviewee's industry had recently upgraded its cutting process. Traditionally, a metal cutting process in his industry was done manually by the use of oxy-acetylene flame. This process is now automated by the use of CNC based plasma cutting machine. The interviewee listed out many of the advantages of this upgradation which were, the achievement of better accuracy, having a lesser rejection rate and a threefold increase in cutting speed. So, the productivity, quality and efficiency of the production has improved because of this upgradation.

The next question was about the obstacles he encountered during the above upgrade and what he did to mitigate them. According to the interviewee, the first challenge is to obtain the funding for the upgradation. This challenge can be mitigated either by using borrowed capital from banks or government schemes that support MSMEs or conversely giving out a part of equity to a third party to obtain interest-free monetary support. And the second challenge is regarding the usage of manpower. Upgraded and modern machinery will require skilled professionals to operate them, and the interviewee found it challenging to train the unskilled employees who would not have any formal education, hire new employees and tackling the ethical dilemma of firing employees as upgraded machines are more capable.

The next question was about the marketing and supply chain strategy in the organisation. In the interviewee organisation, the marketing is done by the top management personnel through personal contacts and has a traditional "word of mouth" marketing strategy. The organisation also employs external marketers through Human Resource agencies. The interviewee organisation also did not have an explicit digital marketing strategy but did offer services through e-commerce platforms such as indiamart.com. And the interviewee organisation had a supply chain strategy to enter into contracts with suppliers depending on the order quantity received.

The next question was about the collection and usage of process data. The interviewee organisation collects the process data but does not use them to make any automatic decisions.

The next question was about the digital features of the product. The interviewee explained that the industry offers two types of digital features with their products – as pre-fitted mountings and as extra accessories. Their digital integration includes the integration of

vacuum or temperature sensors in their product for the purpose of customer data collection.

Based on the responses given by the interviewee in the survey and interview, the following maturity graph is plotted out.
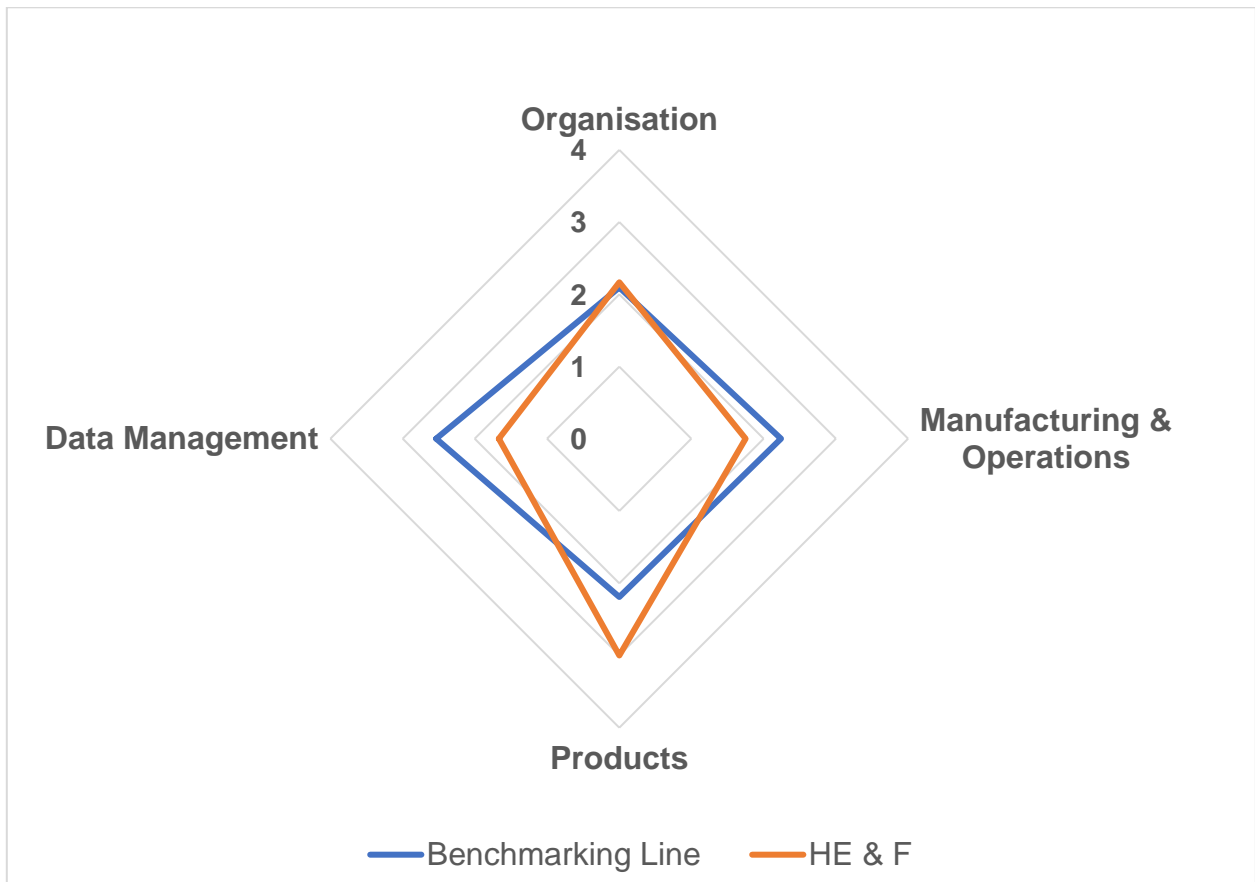


*Figure 35 Maturity graph for HE & F*

The graph in figure 34 shows the maturity of HE & F against the benchmark maturity of the surveyed industries. This tells that although products of HE & F are more advanced than their competitors, where they lack is in the upgradation of their manufacturing technologies and usage of data in their manufacturing.

# 6. Conclusion

This study evaluated the industry 4.0 readiness evaluation tools already present in the market and found that none of the tools were focused on Indian MSMEs. Although some of them were suitable to be used by SMEs, none had a particular focus on Indian MSMEs. The diversity of Indian MSME is skewed towards having more Micro Enterprises with fewer Small & Medium Enterprises. This causes issues in the organisation related to funding the upgradation project or the availability of skilled labour. Further Indian MSMEs encounter marketing hurdles such as the provenance paradox in Indian markets, where people are just more inclined towards buying foreign products.

So, during the upgradation Indian MSMEs must segregate their Industry into four parts – organisation, manufacturing & operations, products and data management and should measure their mindset in the organisation through strategies; technological capabilities of the industry through the level of machine automation, process automation and technologies used; product competency through measuring the customisability of their product and digital features of their product; and level of data management through process data usage and their IT architecture. For an Industry to be Industry 4.0 competent in the market, they need to understand their capabilities, prioritise the projects, form a funding strategy, have an employee education strategy, act & upgrade through small intra-industry projects and keep on continuously upgrading to keep up with the technology.

Further, the survey results validate the constraints of Industry 4.0, with most of the organisations facing resistance in acquiring funds for upgradation, marketing & branding, upgrading existing technology and infrastructure of the industry. Amongst the surveyed industries, it was found out that most industries are falling behind in the implementation of autonomous robots, augmented reality, and additive manufacturing. Also, amongst the surveyed industries, the benchmarking line indicates that the average maturity score is 2.23 and the industries lie in the "Change maker" maturity level.

## 6.1 Limitations of Study

This study relies heavily on secondary data. So the limitations include that many of the important secondary data sources like government reports and company reports are not openly available to all. Also, many paywalled journal articles could not be considered. There might be a loss of valuable secondary data because of this. Errors made by the authors of these secondary data could reflect in this study. As many secondary sources are considered, the validity of the sources considered is a limitation. As the technology will change continuously, an older secondary data source might not be authentic and provide accurate information usable for current times. This can limit the scope of this study.

The number of industries surveyed for this study is very narrow. As the only manufacturing industries from India could answer this survey, due to the limitations of time zone and online meetings and approaching, personal contacts could not be made to get a wider audience, and a sampling size of 54 was achieved. As the Interview is done was online, no techniques to persuade could be used to get more information. The data obtained from interviews is limited as only one person was interviewed.

## 6.2 Future Scope

This study can be improved further by considering more research on the funding aspects of Indian MSMEs and the government schemes that back MSMEs to have a more comprehensive funding strategy. Also, with more market research, the marketing strategy can be introduced.

Further, considering moral dimensions like ethical challenges related to the industry 4.0 implementation must be studied as more than 80% of Indian MSMEs are in rural areas, and many workers whose jobs might be at risk are living "hand to mouth".

With more industries answering the survey and using the maturity model, more data is obtained to improve the tool. With this large amount of organisational maturity data, the accuracy of the benchmarking line shown in figure 33 can be improved.

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